2005-06

Strategic inventory positioning of Navy depot level repairables

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THESIS

STRATEGIC INVENTORY POSITIONING OF NAVY DEPOT LEVEL REPAIRABLES

by

Larry Burton

June 2005

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REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.			
1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** June 2005	**3. REPORT TYPE AND DATES COVERED** Master's Thesis	
4. TITLE AND SUBTITLE: Strategic Inventory Positioning of Navy Depot Level Repairables			**5. FUNDING NUMBERS**
6. AUTHOR(S) Larry D. Burton			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) Navy Inventory Control Point Mechanicsburg PA			**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			**12b. DISTRIBUTION CODE**

13. ABSTRACT (maximum 200 words)

Navy Inventory Control Point (NAVICP) is the principle controller of the Navy's inventory consisting of over 470,000 line items valued at over $30B. NAVICP provides the Fleet the parts necessary to maintain weapons systems. In 2003, NAVICP spent over $444M in transportation charges to fulfill customer requests for repair parts. The research in this thesis is the result of an initiative by NAVICP to study the benefits in modifying their current inventory positioning policy for repairable items. NAVICP wishes to incorporate a strategic inventory positioning policy that reduces transportation costs. This thesis develops the Strategic Inventory Positioning (SIP) model that looks at historical inventory demand and determines the optimal storage locations for NAVICP's inventory of repairable items. SIP provides NAVICP an optimization-based tool to aid in determining the strategic inventory location for each repairable item. Using results from SIP and historical transaction data, a cost comparative analysis of 176 of the highest cost and demand volume items shows that using a new synchronized and scheduled truck delivery system combined with strategically locating both new procurements and returns from repair in depots near high demand concentrations, enables NAVICP to reduce annual transportation costs by an average of $110K per repairable item.

14. SUBJECT TERMS Inventory Positioning, Logistics, Optimization, Linear Programming, Mixed Integer Program			**15. NUMBER OF PAGES** 79
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UL

NSN 7540-01-280-5500 Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

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STRATEGIC INVENTORY POSITIONING OF NAVY DEPOT LEVEL REPAIRABLES

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
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ABSTRACT

Navy Inventory Control Point (NAVICP) is the principle controller of the Navy's inventory consisting of over 470,000 line items valued at over $30B. NAVICP provides the Fleet the parts necessary to maintain weapons systems. In 2003, NAVICP spent over $444M in transportation charges to fulfill customer requests for repair parts. The research in this thesis is the result of an initiative by NAVICP to study the benefits in modifying their current inventory positioning policy for repairable items. NAVICP wishes to incorporate a strategic inventory positioning policy that reduces transportation costs. This thesis develops the Strategic Inventory Positioning (SIP) model that looks at historical inventory demand and determines the optimal storage locations for NAVICP's inventory of repairable items. SIP provides NAVICP an optimization-based tool to aid in determining the strategic inventory location for each repairable item. Using results from SIP and historical transaction data, a cost comparative analysis of 176 of the highest cost and demand volume items shows that using a new synchronized and scheduled truck delivery system combined with strategically locating both new procurements and returns from repair in depots near high demand concentrations, enables NAVICP to reduce annual transportation costs by an average of $110K per repairable item.

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ACKNOWLEDGMENTS

I would like to extend my personal thanks and professional gratitude to my thesis advisor, Professor Johannes Royset, who consistently provided clear guidance and thoughtful feedback along the way.

I appreciate the significant efforts of Professor Robert F. Dell, Professor Javier Salmeron, and Professor Matt Caryle. Without their assistance, I would not have gotten nearly so far.

I would also like to express my sincere thanks to CDR Kent Micheals, LCDR Johnathan Haynes, Mr. Ronald Gabriel and Mrs. Cindi Miceli of Supply Chain Operations Research department, at the Naval Inventory Control Point, Philadelphia, for their kind hospitality during the visit as well as assistance in providing information and data, which has helped tremendously in the completion of this thesis.

As with everything, I have done my wife, Randalle, and my children, Kendall and Kaylen have provided unconditional love and support throughout this thesis research.

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EXECUTIVE SUMMARY

The recent war on terrorism has led to the re-appropriation and downsizing of budgets for spare parts procurement within the Department of Defense (DOD). The Navy has embarked on an initiative called Sea Enterprise that seeks to improve the Navy's organizational alignment, refine logistical requirements, and reinvest savings to transform the Navy to deliver increased combat capability. Navy Inventory Control Point (NAVICP) is critical to achieving these goals. As the principle controller of the Navy's inventory consisting of over 470,000 line items valued at over 30 billion dollars, NAVICP provides the Fleet the parts necessary to maintain weapons systems at a high state of readiness.

In Fiscal Year 2003, NAVICP spent over 444 million dollars in transportation charges to fulfill customer requests for repair parts. The research in this thesis is the result of an initiative by NAVICP to study the benefits in modifying their current inventory positioning policy for repairable items. NAVICP wishes to incorporate a strategic inventory positioning policy that reduces transportation costs. This thesis develops the Strategic Inventory Positioning (SIP) model that looks at historical inventory demand and determines optimal storage locations for NAVICP's inventory of repairable items.

NAVICP manages this repairable inventory within a distribution system operated by the Defense Logistical Agency (DLA). DLA operates 24 defense distribution depots worldwide. Currently DLA is modifying its distribution system to provide its customers with a synchronized and scheduled truck delivery service. This new transportation system should enable NAVICP to provide more reliable and efficient customer service and has the potential to save the Navy millions of dollars in annual transportation costs.

To facilitate this thesis research, NAVICP provided a Microsoft Access database covering the period October 01, 2002 through March 31, 2004. The database consists of 92,662 uniquely identifiable national stock numbers (NSN) accounting for over 2 million requisitions. SIP uses a test data set of 176 depot level repairable (DLR) NSN's representing over 78,900 requisitions consisting of 688 customers using 14 different

modes of shipping. The number of customers is aggregated to 86 demand regions and the shipping modes are consolidated to the eight commonly used modes representing 99% of the materiel shipped. SIP's objective is to minimize transportation costs subject to constraints on the required delivery time and shipping modes utilized. SIP also provides NAVICP the means to conduct valuable "what if" analysis by allowing various modeling parameters to be changed to explore the impact future inventory positioning decisions may have on the inventory system before making actual changes.

SIP is solved with various parameters to determine the number of distribution depots that should be used, as well as the amount and optimal location to place each repairable item and corresponding quantities. A cost comparative analysis is conducted using the storage locations recommended by NAVICP's current inventory positioning policy (using SIP modeling figures as a baseline) and the recommendations obtained from SIP. Current policy dictates that repaired DLRs be stored in the distribution depot closest to the repair facility. This policy usually results in repairable inventory being positioned at depot locations that are not close to high customer demand locations. This equates to increased shipping distance for future materiel requisitions and requires the use of more expensive modes of transportation to ensure materiel reach the customer by the required delivery date.

Actual transportation costs were not available resulting in all calculations being based upon average transportation costs. These costs were obtained from DLA for materiel shipped during Fiscal Year 2004. Using results from SIP and historical transaction data, a cost comparative analysis of 176 of the highest cost and demand volume items shows that using a new synchronized and scheduled truck system combined with strategically locating both new procurements and returns from repair in depots near high demand concentrations, enables NAVICP to reduce annual transportation costs by an average of $110K per repairable item.

LIST OF ACRONYMS

ASO	Aviation Supply Office
ATAC	Advanced Traceability and Control
BOSS	Buy Our Spares Smart program
CNO	Chief of Naval Operations
COG	Cognizance Symbol
CONUS	Continental United States
CWT	Customer Wait Time
DAAS	Defense Automatic Addressing System
DD	Defense Distribution Depot
DI	Document Identifiers
DLA	Defense Logistics Agency
DLIS	Defense Logistics Information Service
DLR	Depot Level Repairable
DMRD	Defense Management Report Decision
DOD	Department of Defense
DODMDS	Department of Defense Materiel Distribution System
DON	Department of the Navy
DODAAC	Department of Defense Acquisition Address Code
DOP	Designated Overhaul Point
DPT	Depot Processing Time
DTS	Defense Transportation System
ERP	Enterprise Resource Planning
FAD	Force Activity Designator
FedEx	Federal Express
FISC	Fleet Industrial Supply Center
FSC	Federal Supply Classification
GAMS	General Algebraic Modeling System
ICPT	Inventory Control Point Time

ILP	Integer Linear Program
IM	Item Manager
IMA	Intermediate Maintenance Activity
IPD	Issue Priority Designators
LRT	Logistic Response Time
MILP	Mixed Integer Linear Program
MRO	Materiel Release Order
NAVICP	Naval Inventory Control Point
NAVSISA	Navy Supply Information System Activity
NAVSUP	Naval Supply Systems Command
NCB	National Codification Bureau
NEXCOM	Navy Exchange Service Command
NIIN	National Item Identification Number
NOLSC	Naval Operational Logistics Support Center
NSN	National Stock Number
NWCF	Navy Working Capital Fund
POET	Point of Entry Time
RDD	Required Delivery Date
RFI	Ready for Issue
RST	Requisition Response Time
RTT	Requisition Take Up Time
SAILS	Strategic Analysis of Integrated Logistics Systems
SDMI	Strategic Management Initiative
SIP	Strategic Inventory Positioning model
SPCC	Ships Parts Control Center
TDD	Time Definite Delivery
TT	Transportation Time
UICP	Uniform Inventory Control Program
UMMPS	Uniform Materiel Movement and Issue Priority System matrix
UND	Urgency of Need

UPS	United Parcel Service
USTRANSCOM	United States Transportation Command

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I. INTRODUCTION

A. OVERVIEW

Historically the Navy's supply distribution system, because of its structure, has had some difficulty meeting the needs of its customers in an effective and efficient manner [Robbins et al. 2004]. Over time, inventory has migrated to dozens of storage locations making each stock point a worldwide distributor resulting in significant materiel delays. This unreliability has caused many customers to turn to faster – more expensive – distribution systems, such as Federal Express (FedEx) and United Parcel Service (UPS) [Robbins et al. 2004].

Defense Logistics Agency (DLA) is currently modifying its distribution system to provide its customers with a synchronized and scheduled truck delivery service [DeVito 2004]. This should allow DLA to provide a more reliable and efficient transportation system, which has the potential to save the military services millions of dollars in annual transportation charges [DeVito 2004]. In Fiscal Year 2003, the Navy Inventory Control Point (NAVICP) spent over 444 million dollars in transportation charges to delivery inventory to their customers [Sax 2005]. The research in this thesis is the result of an initiative by NAVICP to study the benefits in modifying their current inventory positioning policy for repairable items. NAVICP wishes to incorporate a strategic inventory positioning policy that reduces transportation costs.

B. SCOPE OF RESEARCH

This thesis develops the Strategic Inventory Positioning (SIP) model that looks at historical inventory demand and determines the optimal storage locations for NAVICP's inventory of depot level repairable (DLR) items. Specifically, SIP is a mixed-integer linear programming model and focuses primarily on the transportation costs from DLA depots to Navy customers. An examination of the DLR transaction data covering the period October 01, 2002 through March 31, 2004 provides the data to help construct a test set for model implementation.

C. EXPECTED BENEFITS OF STUDY

The primary objective of this study is to provide NAVICP's management an optimization based tool to aid in determining the stocking position for DLR materiel. The creation of the Strategic Inventory Positioning (SIP) model provides valuable "what if" analysis by allowing the NAVICP to change various modeling parameters to explore the impact future business decisions may have on their inventory system before making actual changes. This study also provides recommendations to streamline and improve NAVICP's current stock positioning policy. This allows NAVICP to capitalize upon DLA's new synchronized and scheduled truck delivery system, resulting in a reduction in annual transportation costs and provide customers with more reliable and efficient service.

D. OUTLINE

Chapter II provides background information for this thesis and NAVICP's current inventory positioning policy. Chapter III discusses related distribution system studies and current initiatives to improve the Department of Defense's (DOD's) transportation system. Chapter IV discusses the optimization model, data, modeling assumptions, and the results of the model. Chapter V summarizes the research findings, and presents recommendations for future research.

II. BACKGROUND

A. BACKGROUND

The recent war on terrorism has led to the re-appropriation and downsizing of budgets for spare parts procurement within the Department of Defense (DOD). As a result, military transformation has become a high priority within the Department of Navy (DON). In January 2002, the CNO (Chief of Naval Operations) introduced his vision for the future of the Navy, Sea Power 21 [Clark 2002]. Sea Power 21 is a vision on how the Navy will organize, integrate and transform for future operations. It consists of three pillars: (1) Sea Strike - Projecting Precise and Persistent Offensive Power, (2) Sea Shield - Projecting Global Defensive Assurance, and (3) Sea Basing - Projecting Joint Operational Independence. Sea Enterprise is the central part of this strategic triad that seeks to improve organizational alignment, refine logistical requirements, and reinvest savings to transform the Navy and deliver increased combat capability. The CNO is tasking all Navy commands to harvest efficiencies within its organization through technology insertion, improved business practices, and the recapitalization of infrastructure cost.

The following sub-sections provide basic information on the Navy's inventory management system as well as provide a summary of the organizations and policies that effect its operation.

1. Navy Inventory System

Inventory management is critical to achieving and sustaining Naval Fleet readiness at the required levels to support military strategy. When equipment fails, the speed at which it is restored is crucial to mission success and depends on the availability of spare parts. NAVICP provides the fleet with these spare parts through a multi-tiered system of retail and wholesale inventory. Retail inventory refers to spare parts that are stored shipside or planeside in accordance with standardized spare parts allowance lists. Funds for retail spare parts come from the Navy's procurement and operations accounts. Whereas, wholesale inventory refers to spare parts the Navy buys to replenish retail

inventory. Initially Navy program managers tasked with developing weapon systems purchase parts directly from vendors using money from the procurement accounts. However, once a weapon system is fully developed and integrated into the fleet, NAVICP assumes full responsibility for supporting that system through funding provided by the NWCF (Navy Working Capital Fund). At this point, fleet customers use funding from outfitting procurement and operations accounts to purchase parts from NAVICP wholesale inventory. NAVICP's wholesale system functions as an intermediary by purchasing spare parts from vendors with NWCF dollars, and then reselling these parts to fleet customers.

NAVICP further delineates these spare parts into two specific categories: consumable and repairable inventory. Consumable items are often inexpensive parts, which once incorporated into the weapon system become unfit for further service. Examples of consumable items are gaskets, hoses, and bushings. Repairable items are usually expensive parts, commonly called depot level repairables (DLRs) because repair is less costly than new purchases. Repairable items have a dedicated repair cycle that makes them more of a challenge to manage. Engines, motors, and electronic boards are examples of DLR items. This thesis deals exclusively with NAVICP's DLR inventory.

The nature of the Navy repair process has a direct bearing on how and where DLR inventory is stored before and after entering the repair cycle. First, a review of the repair cycle is given. In order to repair DLRs the Navy inventory system uses three unique levels of maintenance. These levels are organizational level, intermediate level, and depot level. The organizational level is the lowest maintenance echelon and consists of all maintenance actions within the capability of ship force [DOD 2003]. This maintenance normally includes periodic checks, visual inspections, cleaning, very limited servicing, and some removal and replacement of components. The intermediate level consists of maintenance requiring a higher skill, capability, or capacity than that of the organizational level. Navy Intermediate Maintenance Activity (IMA) personnel on or at tenders, repair ships, aircraft carriers, Aircraft Intermediate Maintenance Departments, submarine refit and support facilities, Shore IMAs, and Naval Reserve IMA Maintenance Facilities, normally accomplish this maintenance [DOD 2003]. Depot level maintenance is that maintenance which requires skills or facilities beyond the level of the

organizational and intermediate levels and is performed by naval shipyards, private shipyards, naval ship repair facilities, or item depot activities. This maintenance level also includes approved alterations and modifications, which update and improve military and technical capabilities [DOD 2003].

When a DLR becomes unusable it is removed from the affected weapon system and sent to the closest Advanced Traceability and Control (ATAC) center for proper identification, packaging, and shipping. The DLR is then shipped to the nearest designated overhaul point (DOP) where it enters the repair cycle. Once repair of the DLR is complete, it is then sent back to the DOP for re-packaging and shipping to the closest DLA distribution depot. This policy allows NAVICP to reduce the first leg of the transportation costs, from the vendor or repair facility, but usually increases the transportation costs during the last leg, shipment of the part from the depot to the customer.

Currently there are over four million supply items in the DOD Supply System. The Navy Supply System alone stocks over one million of these items. All of which, is assigned a unique national stock number (NSN). An NSN is a 13 digit stock number assigned by the Defense Logistics Information Service (DLIS). This NSN consists of a four digit Federal Supply Classification (FSC), and a nine digit National Item Identification Number (NIIN). The NIIN consists of a two-digit National Codification Bureau (NCB) code and seven digits, which, in conjunction with the NCB code, uniquely identify each NSN item in the federal supply distribution system [NAVSUP 2004]. A Cognizance Symbol (COG) is a two-digit alphanumeric prefix assigned to each NSN to identify particular types of inventory. See Figure 2.1 as an example.

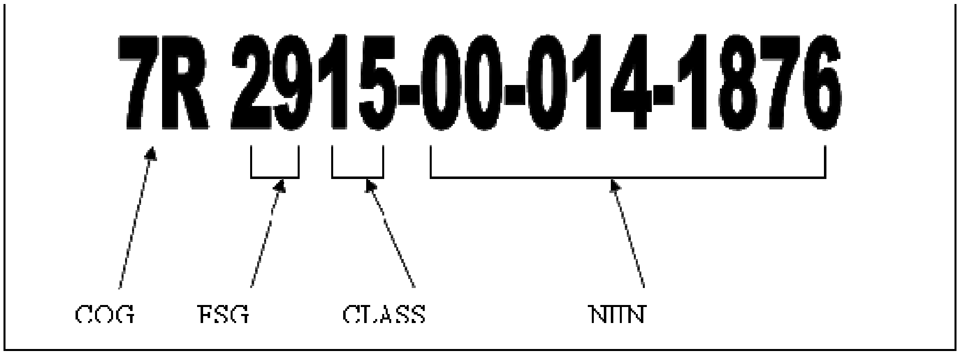

Figure 2.1 COG and NSN Example

Figure 1.1 shows the COG and NSN for an item named "Aircraft Fuel Tank Float Valve." "7" indicates the item is a DLR managed by NAVICP. "R" means the part is an aviation item. "29" identifies the item as belonging to FSG "Engine Accessories." "60" indicates the item belongs to "Engine Fuel System Components, Aircraft and Missile Prime Movers" Class. The NIIN uniquely identifies the item.

2. Navy Supply System Command (NAVSUP)

The primary mission of the Navy Supply System Command (NAVSUP) is to provide U.S. Naval forces with quality supplies and services. With headquarters in Mechanicsburg, Pa., and employing a worldwide workforce of more than 24,000 military and civilian personnel, NAVSUP oversees logistics programs in the areas of supply operations, conventional ordnance, contracting, resale, fuel, transportation, security assistance, and food service. In addition, NAVSUP is responsible for quality of life issues for all Naval forces, including food service, postal services, Navy Exchanges, and movement of household goods [NAVSUP 2005].

NAVSUP's overall mission is to provide the Fleet what they need when they need it. NAVSUP's command organization (see Figure 2.2) comprises five principle components.

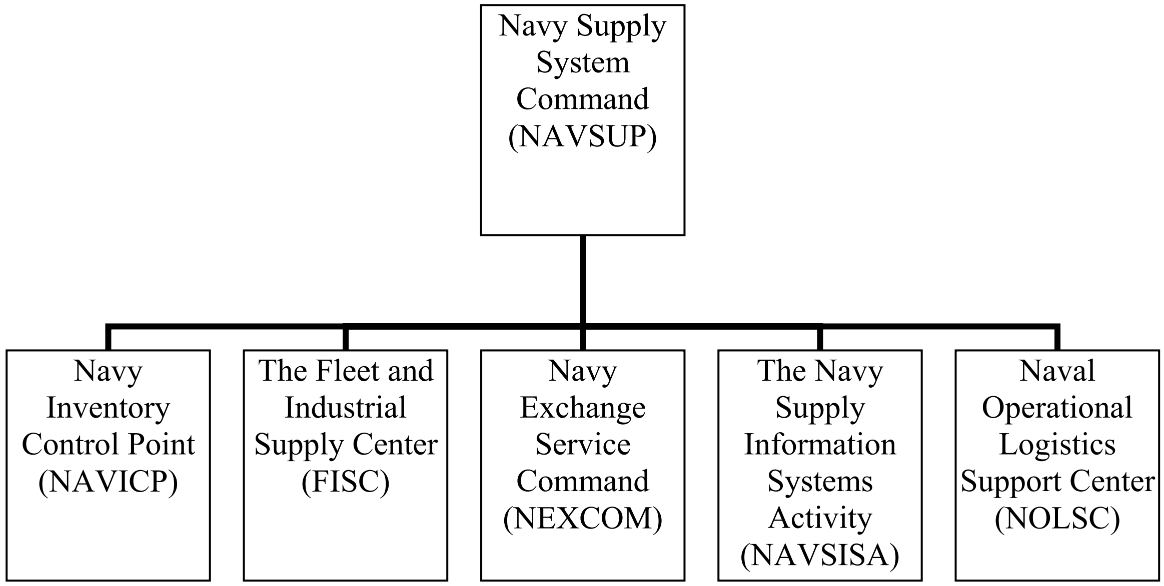

Figure 2.2 NAVSUP Organization Chart

The Navy Exchange Service Command (NEXCOM) includes 110 Navy exchanges, 41 Navy lodges and 186 ships stores. Sales exceed $2.0B annually and generate over $67M in profits that support Morale, Welfare and Recreation programs ashore and afloat. NEXCOM also manages the Navy clothing program, providing both uniforms and specialized protective clothing to the Navy [NAVSUP 2005].

The Fleet and Industrial Supply Centers (FISCs) provide a variety of logistics support services and products to include materiel management, contracting, transportation, fuel services, customer service, hazardous materiels management, household goods movement support, consolidated mail services and supply consultation [NAVSUP 2005].

The Navy Supply Information Systems Activity (NAVSISA) is the Navy premier Central Design Agency with responsibility to design, develop and maintain information systems supporting numerous shore activities in the functional areas of logistics, transportation, finance and accounting, and inventory modeling [NAVSUP 2005].

The Naval Operational Logistics Support Center (NOLSC) serves as the focal point for enhancing operational commanders materiel readiness by providing innovative solutions to logistical challenges. NOLSC is also the NAVSUP supply chain manager

and service provider for transportation, petroleum and ordnance logistics services for the Navy, Marine Corps, Joint and Coalition Forces [NAVSUP 2005].

3. Navy Inventory Control Point (NAVICP)

NAVICP exercises principle control over 470,000 items of supply consisting of repair parts, components and assemblies worth over $27 billion with annual sales of $3.8 billion in support of both maritime and aviation systems for the Navy and Marine Corps [NAVICP 2005].

The mission of NAVICP is to provide program and supply support for the weapons systems that keep our naval forces mission ready. NAVICP exercises centralized control over Navy unique repair parts, components and assemblies that keep ships, aircraft and weapons operating. NAVICP also provides logistics and supply assistance to friendly and allied nations through the Foreign Military Sales program.

NAVICP accomplishes its mission through a single command organization operating as a tenant activity of Naval Support Activities in Mechanicsburg and Philadelphia. NAVICP was established in 1995, following the merging of Ships Parts Control Center (SPCC) in Mechanicsburg and Aviation Supply Office (ASO) in Philadelphia.

The primary activity for the Philadelphia site is aviation and weapon system support. Among the aircraft supported are the F/A-18 and the V-22 as well as multiple engines, common avionics, and support equipment. In contrast, their Mechanicsburg counterpart handles support for hull, electrical, mechanical, and electronic components and repair parts for ships, submarines and weapon systems.

The NAVICPs manage the inventory of supply items under their cognizance and store them in a distribution system consisting of both naval ships and shore supply activities. In order to avoid inventory shortages, NAVICP must accurately forecast demand for these spare parts and factor in lead times for procurement and necessary repair actions. This is the responsibility of the Item Managers (IMs) at the NAVICPs. They make decisions on whether to repair or purchase new DLRs. They have the primary responsibility of ensuring enough spare parts are available where and when

needed to support Fleet operations. Individual IMs manage hundreds to thousands of spare parts pertaining to their particular weapon systems. These efforts include materiel procurement, repair coordination, inventory positioning, excess materiel disposal, and budgeting and supply performance analysis. IMs manage this large inventory of spare parts, using a legacy computer program, Uniform Inventory Control Processing System (UICP). UICP positions materiel at various Navy ashore supply activities (e.g. FISCs, Naval Air Stations, Trident Refit Facility, and Contractor warehouses). The program retains inventory control of materiel through an extensive stock reporting system; and provides technical assistance and cataloging services to the supply system and to its customers.

4. Defense Logistics Agency (DLA)

The Defense Logistics Agency (DLA) headquarters is in Fort Belvoir, VA with field activities located in 48 states and over 28 countries. DLA provides worldwide logistics support for the missions of the military services under conditions of peace and war. DLA also provides logistics support to other DOD Components and certain Federal agencies, foreign governments, international organizations, and others as authorized. If DLA were a civilian corporation it would be ranked number 55 in the Fortune 500 with annual sales worth over $28.9 billion, inventory of over 4.6 million line items, and a work force consisting of over 22,500 personnel [DLA 2005].

The origins of DLA date back to World War II when America's huge military expansion required rapid procurement of great amounts of munitions and supplies. After the war, a presidential commission recommended the centralization of common military logistics support management and the development of a uniform financial management system. Acting upon this recommendation, all the military branches began to systematically buy, store, and issue all consumable items through DLA [DLA 2005].

Relating to Navy wholesale inventory, DLA is responsible for storing, handling, and issuing upon request from the service all Navy materiel. To conduct this tasking, DLA operates 24 defense distribution depots (DDs) worldwide to receive, store, and distribute all DOD inventory. However, NAVICP is responsible for the management of

this inventory to include procuring, disposing, determining the stock level, and positioning within DLA's distribution network. A map of DLA's current distribution network is provided in Figure 2.3. All of these DDs are co-located with a military activity except Columbus, Richmond, Susquehanna, and San Joaquin. DDs co-located with Navy FISC include Jacksonville, Norfolk, Pearl Harbor, Puget Sound, San Diego, and Yokosuka.

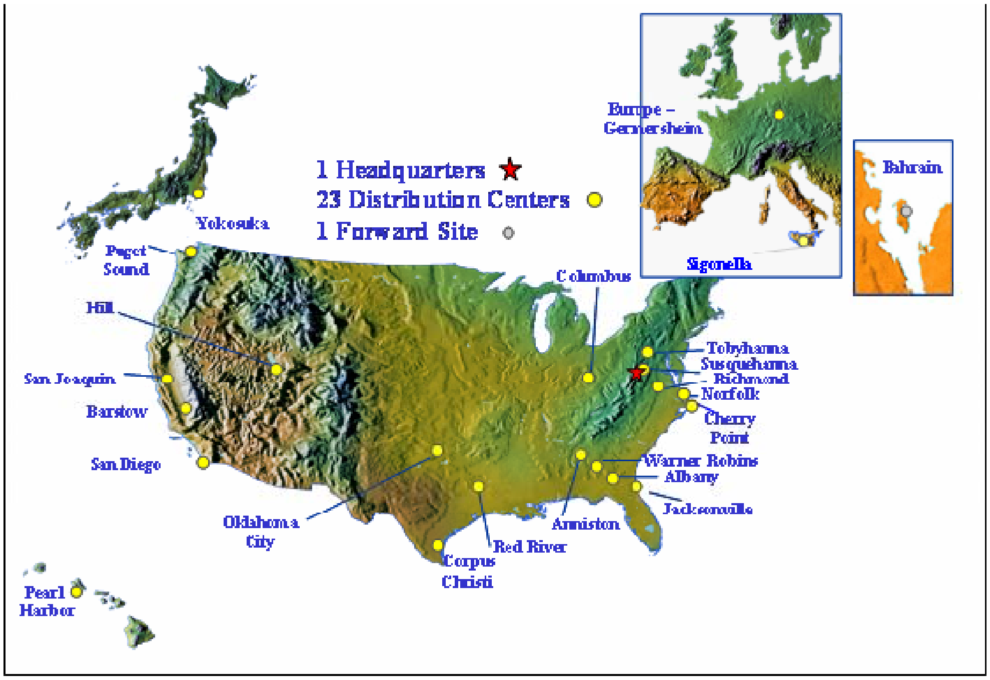

Figure 2.3: Map of DLA Distribution

Modified from [DLA 2005] figure presents DLA's distribution network, which includes 24 DDs and one Forward logistics site located OCONUS in Bahrain. DLA's Primary Distribution Sites (PDS) are located at Susquehanna PA and San Joaquin, CA.

5. United States Transportation Command (USTRANSCOM)

The United States Transportation Command (USTRANSCOM) headquarters is at Scott Air Force Base, IL. USTRANSCOM interface between DOD shippers and the commercial transportation carrier industry. USTRANSCOM establishes, executes, and validates transportation contracts for the movement of troops, supplies, and equipment through the Defense Transportation System (DTS).

B. MEASURE OF EFFECTIVENESS

The Navy spends $1,775M annually to repair and procure DLRs to maintain high Fleet readiness levels [Sax 2005]. Of major concern to the Navy is how much time it takes the Navy supply system to ship parts to its customers. NAVICP uses Logistic Response Time (LRT) as a measurement to define how effective it is at providing the right inventory in the right quantity to maintain these high readiness levels. Today Customer Wait Time (CWT) is replacing LRT as the metric of choice. A brief summary of each and the differences are given in the following paragraphs.

1. Logistics Response Time (LRT)

LRT measures the time from submission of the customer request until the Defense Automatic Addressing System (DAAS) receives an electronic acknowledgement of materiel receipt.

Measurement of LRT is in days, and consists of the following components: Requisition Response Time (RST), Point of Entry Time (POET), Inventory Control Point Time (ICPT), Depot Processing Time (DPT), Transportation Time (TT), and Requisition Take Up Time (RTT). RST measures the time elapsed from the initial customer submission until receipt in DAAS. POET measures the time elapsed between the local FISC screening their inventory for the part to the time it takes to refer the requisition to NAVICP. ICPT is a measurement of the time it takes for the Inventory Control Point to submit the Materiel Release Order (MRO) to the issuing depot. DPT measures the time it takes the depot to ship the requisition. TT measures the time elapsed from release of the DLR from the issuing depot to the carrier until the customer placing the initial requisition for the item receive the parts. Lastly, RST measures the time it takes the customer to transmit a receipt acknowledgement back to DAAS.

This thesis investigates the possibilities of shortening one of these components, TT, by strategically locating materiel within the DLA distribution network to allow quicker and cheaper modes of transportation to be utilized.

2. Customer Wait Time (CWT)

In the near future CWT will replace LRT as the principle measure of effectiveness. Currently LRT only measures wholesale inventory transaction time. Once the Navy supply system builds additional data collection functions into DAAS, CWT provide a means to measure the time for both wholesale and retail inventory transactions.

3. Time Definite Delivery

A new concept in the civilian sector is Time Definite Delivery (TDD). TDD is a concept that measures the logistic system's capability of delivering materiel to its customers within a specified timeframe with 85 percent reliability [DAU 2005]. This new metric computes delivery performance from statistical calculations requisitions that pass through the supply system. This allows DOD to gauge the supply systems ability to provide individual customer support and aid in computing the performance of the supply chain. It is also for possible use in future contract negotiations and performance agreements.

C. NAVICP INVENTORY POSITIONING POLICY

IMs at NAVICP use a series of applications and reports in the UICP to compute both retail and wholesale inventory levels. UICP provides inventory forecast reports; computes projected service levels; and estimates inventory response time for immediate inventory fills. IMs also rely on UICP reports to determine inventory positioning locations for the weapon systems they manage. UICP also makes recommendations on where to position new DLR procurements and returns from repair. UICP makes its recommendations for wholesale inventory positioning based on the historical percentage of worldwide demand. This means if 25% of worldwide demand comes from the Norfolk, VA region; then 25% of the worldwide inventory go to that region.

IMs may choose to ignore UICP's positioning recommendation if:

a. there is a lack of proper storage capacity or handling capability at the recommended storage facility;

b. repaired parts at repair activities are in close proximity to a distribution depot;

c. transportation of new purchases to one location instead of multiple locations can reduce transportation costs; and

d. the number of multiple locations can be reduced due to low historical demand in a region.

A few other concerns relating to UICP positioning recommendations are as follows: UICP does not explicitly consider LRT or CWT from the distribution depot to the customer, UICP does not consider different depot-to-depot inventory transaction costs such as receipt and issue costs; and UICP does not consider inbound and outbound transportation costs.

A few NAVICP specific policies relating to inventory positioning are:

a. Ready-for-Issue DLRs returned from repair depots are to be positioned at the closest DD to minimize transportation cost.

b. Distribution facilities not co-located with Navy FISCs are not normally considered as distribution points (except for DDs Cherry Point, NC and Ingleside, TX that are co-located with a repair depot and Navy Base/FISC San Diego DLA Detachment, respectively);

c. UICP has a redistribution program that recommends inventory movements between depots to balance projected regional demands. This function is currently disabled because it makes monthly inventory movements recommendations that increases transportation costs [Reich 1999].

This thesis looks at historical demand and uses it as the backdrop to determine future inventory positions. Where current NAVICP policy uses a "closest to vendor/repair facility policy" to reduce initial transportation costs, this thesis studies a "closest to customer policy." The idea behind using a "closest to customer policy," is it increases Fleet operational readiness and allows NAVICP to respond to customer requisitions quicker and at a cheaper cost. For example, according to current policy after DLRs have been repaired they are transported to the nearest distribution depot. The

"closest to customer" policy recommends these repaired items be transported to a distribution depot close to the customer using the scheduled truck system in DLA's distribution network. The cost benefits come into play when the customer requisitions the part. Because the part is positioned close to the customer, based on historical demand, NAVICP is able to provide the part quicker and cheaper using DLA's synchronized and scheduled truck system. Thereby ensuring the materiel is shipped and received by the customer's required delivery date. Current policy usually requires the use of more expensive modes of transportation because materiel is not locally positioned. Table 2.1 shows the modes of shipment commonly used to deliver DLR materiel to customers between October 01, 2002 and March 31, 2004, and illustrates the current reliance on fast but expensive modes.

NAME	Qty	Annual Cost
Air, Small Package Carrier	189,027	$ 4,776.3 K
Local Delivery by Commercial Truck	158,424	$ 205.9 K
Surface Small Package Carrier	23,902	$ 134.5 K
Commercial Air Freight	14,993	$ 4,138.6 K
Government Truck	13,498	$ 0.0 K
Motor, Truckload	13,125	$ 1,107.7 K
Motor, Less Than Truckload	8,947	$ 859.9 K
Scheduled Truck	8,767	$ 92.0 K
Surface Parcel Post	809	$ 4.4 K
Bearer Walk-Through	777	$ 0.3 K
Military Sealift Command (MSC)	630	$ 0.0 K
Air Parcel Post	409	$ 3.8 K
Air Mobility Command	282	$ 0.0 K
Air Freight Forwarder	206	$ 19.4 K
Organic Military Air	19	$ 0.0 K
Water, River, Lake, Coastal	5	$ 0.0 K
Surface, Freight Forwarder	4	$ 5.4 K
Pipeline	3	$ 0.0 K
SEAVAN	2	$ 0.0 K
Trailer and Flatcar	1	$ 0.0 K
Totals	433,830	$ 11,348.2 K

Table 2.1: Ship Mode

This table presents a breakdown of the transportation modes used to ship DLR materiel during the period October 01, 2002 through March 31, 2004. The most commonly used mode is Air, Small Package Carrier and Commercial Air Freight that accounts for 44% of the materiel shipped and 37% of annual transportation costs, respectively.

III. RELATED STUDIES AND CURRENT INITIATIVES

A. PREVIOUS STUDIES OF DISTRIBUTION NETWORKS

This section reviews studies of civilian distribution networks. It also considers six previous studies of DLA's distribution network. A review of these studies highlight similarities with SIP's modeling and data aggregation techniques.

1. Civilian Distribution Network Studies

There is vast literature relating to distribution networks using methods such as heuristics algorithms, column generation, branch and cut, risk pooling, and mixed integer linear programs. These models address the strategic issues of where to build warehouses and which customers to place in each warehouse delivery region. Typically, the mathematical models for these problems involve two sets of decision variables. The first set is the location variable, which determines whether a facility should be located at a candidate facility site. The second set is the assignment (allocation) variable, which determines the assignment of customers to the open facilities. A summary of these models can be found in texts by Hurter [1989], Daskin [1995], Drezner [1995], Kasilingam [1998], Ballou [1999], and Drezner and Hamacher [2002].

Recently, several new studies combine inventory management and routing decisions [Chan et al. 1998] and [Kleywegt et al. 2000]. Also, several models combine location and routing decisions; [Berman et al. 1995], and [Berger et al.1998].

While there is much logistics literature dealing with designing a distribution network, locating facilities and assigning customers; little deals with identifying where to position NAVICP's specific inventory within DLA's pre-existing distribution network.

2. DLA Distribution Network Studies

The Joint Service Commission conducted the first major study of DOD's supply system in 1978. The Department of Defense Materiel Distribution System (DODMDS) study analyzed DOD's distribution system using a mixed integer program to minimize operating costs and a simulation model to evaluate system and depot capacities. The data

used in this study covered all the supply classes except bulk petroleum, perishable subsistence, ammunition, chemical, biological, and radiological items, industrial plant equipment, and some major end items [DODMDS 1978]. This study projected that an annual saving of $100 million is possible through the closure of nine depots and the positioning of certain materiel closer to the customer. DODMDS also provides an aggregation scheme for depots, procurement sources, inventory groups, and customer clusters.

Another study of the DOD distribution system was conducted 1989 at the behest of President George H. W. Bush to reduce the military budget and the size of DOD. This study resulted in two reports, The Defense Management Report Decision (DRMD) 901 [DMRD 1989a] and 902 [DRMD 1989b]. DRMD 901 started the process of reducing DOD inventory and DRMD 902 seeks to improve inventory management through the consolidation and centralization of warehouses and depots. DRMD 901 aimed at lowering supply system costs and resulted in saving over $2.5 billion during the FY 91-95 period [DRMD 1989a]. These savings were realized through a reduction in procurement lead times, reduced inventory levels, and lower materiel procurement costs through the implementation of the Buy Our Spares Smart (BOSS) program. DRMD 902 aimed at consolidating defense supply depots and resulted in a saving of over $1.2 billion during the FY 91-97 period [DRMD 1989b]. This was achieved through (1) the consolidation of the physical distribution of all supply depots under DLA, (2) the reduction of excess peacetime capacity by closing under utilized depots and using remaining capacity better, and (3) the reduction of management cost through reduced base and headquarters cost.

Hobbs and Lanagan [1992] evaluate alternative stocking polices for DLA in order to reduce first leg transportation costs - costs to deliver materiel from vendor location to DLA depot. The study analyses DOD demand patterns and determines that demand is not geographically stable and there is significant variability for fast moving-high demand items. Additionally, the study found that a “closest to vendor” stocking policy is potentially more economical for DLA than a “closest to customer” policy. Hobbs and Lanagan [1992] did not look into the effects this policy change would have on combat

readiness nor the costs involved in implementing the policy within DLA's inventory management system.

Holmes [1994] uses a commercial network design product known as Strategic Analysis of Integrated Logistics Systems (SAILS) to analyze DLA's distribution network. This study uses similar aggregation schemes to those derived in the DODMDS study to aggregate inventory, customer, supplier, and transportation modes to use in SAILS. Holmes concludes that DLA is not using its depots to capacity and proposes depot closure candidates to support the 1995 budget reduction.

Reich [1999] analyzes positioning of single DLR line items within seven network permutations and considers implications of aggregated results on inventory positioning strategies. The study uses 57 DLR line items, a simplified six mode transportation scheme, and an aggregated customer scheme based on Holmes study to build an integer linear program (ILP). This ILP determines the optimal position of one or more DLR line items to select which should be placed at a contracted FedEx hub for shipment upon receipt of a customer requisition. This study differs from Reich [1999] because it looks at identifying the best locations to store NAVICP DLR inventory within the entire DLA distribution network, not just at a contracted FedEx hub.

Kaplan [2000] analyzes NAVICP's inventory positioning policy and develops a heuristic algorithm, which positions Navy wholesale inventory within DLA's distribution network. This study is the result of analysis using different scenarios in which transportation and depot costs were minimized, transportation costs alone were minimized, and then distance was minimized. Kaplan used a demand history file consisting of 32,521 unique supply items with at least one monthly demand in an 18-month period.

The result of the Kaplan study suggests:

(1) DLA depots currently have excess throughput capacity available;

(2) Distributing issue group-2 next day increases the total distribution cost by only 15%;

(3) Deleting depots that are not collocated with Navy bases or that have high depot costs barely affects the total distribution costs and;

(4) Storing items, or even complete item groups at a limited number of depots does not increase transportation and depot costs, and thus may lower total costs including the fixed costs associated with positioning items.

The Kaplan [2000] uses a greedy heuristic algorithm that does not provide an optimal solution, which is the purpose of this study.

The intent of this study is not to determine ways to reduce DLA's operating costs as in Hobbs and Lanagan [1992]. This thesis uses slight modifications to the aggregation schemes in the DODDMS [1978] and Holmes [1994], and the concepts and ideas of Reich [1999] and Kaplan [2000] to build a MIP that provides an optimal solution to NAVICP's inventory positioning question. However, this study does not look at trying to determine which distribution depots to keep open as in the Holmes [1994]. Nor is this study trying to identify materiel that should be relocated from DLA's storage facilities to a FedEx materiel expediting facility as in the Reich's study. NAVICP is currently considering ending the use of the FedEx hub as a distribution depot [SAX 2005]. This thesis seeks to find an optimal solution, not a sub-optimal solution as in the Kaplan study, to the problem of determining where to position DLR inventory within the DLA distribution network in order to reduce annual transportation costs and improve customer wait time.

B. CURRENT INITIATIVES

This section discusses current initiatives underway that could lead to improvements in the defense transportation system. These initiatives also address changes in business rules and operating procedures that promise to reduce operating cost.

1. Strategic Distribution Management Initiative

In 2000, USTRANCOM and DLA implemented an initiative know as Strategic Distribution Management Initiative (SDMI) that streamlines DOD's global distribution system. SDMI integrates the key elements of stock positioning and transportation to

drive down transportation costs and CWT while improving the quality and reliability of service [SDMI 2002]. In 2001, FISC San Diego repositioned 100 NSNs to Defense Depot San Joaquin, CA, resulting in an average 8.6-day reduction in CWT [SDMI 2002]. According to Charlie Nye, Director of Strategic Planning at DLA, "An effective distribution system starts with having stock in the right place, which allows distribution centers to consolidate large volumes of freight for major customers; it also provides the opportunity for scheduled synchronized deliveries and low-cost transportation" [SDMI 2002]. The goal of this thesis is to identify the optimal stock locations to store DLR inventory to allow NAVICP to capitalize upon this new initiative.

2. Enterprise Resource Planning

Currently NAVICP is implementing a new program, Enterprise Resource Planning (ERP), which allow them to identify areas within their supply chain that could benefit from business process improvements. One of the main tenets of this program focus on materiel management with the objective of strategically positioning inventory to reduce costs.

While Enterprise Resource Planning (ERP) will not solve every problem, it offers a disciplined approach to effect business process change and implement industry common best practices. The Navy ERP Program is a priority for the Secretary of the Navy and is an enabler to modernize business processes. It provides an end-to-end business management system that transforms and standardizes Navy business processes for acquisition, financial, maintenance, supply chain, and workforce management operations into a single system. In the future, integration of these processes will: streamline the organizational infrastructure; maximize synergy in business functions; and provide rapid, accurate response to the warfighter.

By combining the efficiencies in improved business processes and procedures identified in ERP, and the reliability and cost savings from SDMI, NAVICP will be able to provide the customer the right part, in the right quantity, at the right price. Until ERP is fully operational, NAVICP requests this study to analyze current inventory positioning policies to see if a change in positioning policy reduces transportation cost from dollars per pound to pennies per pound.

IV. STRATEGIC INVENTORY POSITIONING MODEL

A. INTRODUCTION

This chapter presents MIPs, discusses the data set and gives a description of the assumptions made to build the SIP model. SIP is an optimization model, which determines the optimal storage locations for NAVICP's DLR inventory within the DLA distribution network. We implement SIP in the General Algebraic Modeling System (GAMS) [GAMS 2005] using the XA solver [XA 2003].

B. MIXED INTEGER PROGRAM

Basic Model

Indices:

i	Items (176 unique DLR NIIN's)
c	Customer demand regions (86 aggregated customer demand regions)
d	Distribution depots (18 CONUS DLA depots)
m	Shipping modes (8 shipping modes)

Data:

WT_i	Weight of each item i (pounds).
$DEMAND_{i,c}$	Historical demand of item i from customer c (items).
$DIST_{c,d}$	Distance from each customer region c to each depot d (miles).
$RDD_{i,c}$	Historically required delivery dates of item i for customer c (days).
$COST_m$	Cost associated with each shipping mode m (dollars/lb - miles).
$MAXDEPOT_i$	Max number of depots with item i.
$DELTIME_{c,m,d}$	Needed delivery time from d to c based on UMMIPS standards using mode m (days).

$STOCK_{i,d}$ Amount of item i stored at depot d (items).

Non-negative Decision Variables:

$X_{i,m,d,c}$ Quantity of item i to ship via mode m from depot d to customer c (items).

Binary Decision Variables:

$Y_{i,d}$ One, if item i is stored at depot d.

Mathematical Formulation: [for a given *i*]

Objective Function:

$$\min \sum_{m,d,c} X_{i,m,d,c} * WT_i * DIST_{c,d} * COST_m$$

Subject to:

$$\sum_{m,c} X_{i,m,d,c} \leq Y_{i,d} * STOCK_{i,d}, \qquad \forall d \qquad (1)$$

$$\sum_{m,d} X_{i,m,d,c} = DEMAND_{i,c}, \qquad \forall c \qquad (2)$$

$$\sum_{m,d} \max(0, DELTIME_{c,m,d} - RDD_{i,c}) * X_{i,m,d,c} = 0, \qquad \forall c \qquad (3)$$

$$\sum_{d} Y_{i,d} \leq MAXDEPOT_i \qquad (4)$$

$$X_{i,m,d,c} \geq 0, \qquad \forall m,d,c \qquad (5)$$

$$Y_{i,d} \in \{0,1\}, \qquad \forall \mathrm{d} \qquad (6)$$

C. EXPLANATION OF FORMULATION

The objective function of the model expresses the transportation costs to ship NAVICP's DLR inventory from the distribution depot to the customer within the required delivery date specified by the customer. (Note that the formulation decomposes with respect to each DLR NIIN.) Constraint (1) ensures the number of DLRs shipped

from a depot does not exceed the actual quantity of stock available at that depot. Constraint (2) ensures customer demand is satisfied. Constraint (3) ensures the shipping mode chosen can deliver a DLR within the required delivery timeframe. Such a constraint is not explicitly required but, shows what variables would not exist. Constraint (4) allows the user to choose the maximum number of storage depots thereby placing a max bound on SIP to position DLR items. Constraint (5) ensures non-negative flow of materiel through the network. Constraint (6) is a binary variable that assumes the value of one for each depot SIP chooses to use and a value of zero otherwise.

D. EXTENDED MIP FORMULATION

The Basic Model does not allow delays in the Required Delivery Date (RDD) but it may be useful to look at what if situations dealing with some slack in the RDD. Costs associated with materiel delays are not easily quantifiable because they relate to readiness and the ability of the customer to perform their assigned mission. To allow delays in the RDD we apply a penalty, *PEN*, for exceeding the RDD regardless of the quantity of materiel shipped. This extension gives rise to SIP which is defined as follows using much of the same notation as the Basic Model.

SIP Model

Indices:

i	Items (176 unique DLR NIIN's)
c	Customer demand regions (86 aggregated customer demand regions)
d	Distribution depots (18 DLA depots)
m	Shipping modes (7 shipping modes)

Data:

WT_i	Weight of each item i (pounds).

$DEMAND_{i,c}$ Historical demand of item i from customer c (items).

$DIST_{c,d}$ Distance from each customer region c to each depot d (miles).

$RDD_{i,c}$ Historically required delivery dates of item i for customer c (days).

$COST_m$ Cost associated with each shipping mode m (dollars/pound - mile).

$MAXDEPOT_i$ Max number of depots with item i.

$DELTIME_{c,m,d}$ Needed delivery time from d to c based on UMMIPS standards using mode m (days).

$PEN_{i,c}$ Penalty per day of exceeding $RDD_{i,c}$ for each depot and mode of shipment (dollars/days).

$STOCK_{i,d}$ Amount of item i stored at depot d (items).

Scalar:

M Sufficiently large constant (items).

Non-negative Decision Variables:

$X_{i,m,d,c}$ Quantity of item i to ship via mode m from depot d to customer c (items).

$T_{i,m,d,c}$ Time in excess of RDD to ship item i via mode m from depot d to customer c (days).

Binary Decision Variables:

$Y_{i,d}$ One, if item i is stored at depot d.

$Z_{i,m,d,c}$ One, if item i is shipped from depot d to customer c using mode m.

Mathematical Formulation: [for a given *i*]

Objective Function:

$$\min \sum_{m,d,c} X_{i,m,d,c} * WT_i * DIST_{c,d} * COST_m + \sum_{m,d,c} T_{i,m,d,c} * PEN_{i,c}$$

Subject to:

$$\sum_{m,c} X_{i,m,d,c} \le Y_{i,d} * STOCK_{i,d}, \qquad \forall d \qquad (7)$$

$$\sum_{m,d} X_{i,m,d,c} = DEMAND_{i,c}, \qquad \forall c \qquad (8)$$

$$DELTIME_{c,m,d} * Z_{i,m,d,c} \le RDD_{i,c} + T_{i,m,d,c}, \qquad \forall m,d,c \qquad (9)$$

$$X_{i,m,d,c} \le M * Z_{i,m,d,c}, \qquad \forall m,d,c \qquad (10)$$

$$\sum_{d} Y_{i,d} \le MAXDEPOT_i \qquad (11)$$

$$X_{i,m,d,c},\ T_{i,m,d,c} \ge 0, \qquad \forall m,d,c \qquad (12)$$

$$Y_{i,d} \in \{0,1\}, \qquad \forall \mathrm{d} \qquad (13)$$

$$Z_{i,d} \in \{0,1\}, \qquad \forall \mathrm{d} \qquad (14)$$

E. EXPLANATION OF SIP FORMULATION

The objective function of the model minimizes the transportation costs to ship NAVICP's DLR inventory from the distribution depot to the customers. This objective function includes the penalty, $PEN_{i,c}$, for exceeding $RDD_{i,c}$. For a sufficiently large penalty all RDDs are satisfied and SIP is equivalent to the Basic Model. However, SIP generally provides more flexibility in determining storage locations. Most constraints in SIP are identical to those in the Basic Model. The constraint in (9) ensures the shipping mode chosen can deliver DLR inventory within the required delivery timeframe. In this constraint, $T_{i,m,d,c}$ is a variable, which in conjunction with $PEN_{i,c}$, in the objective function, adds a penalty to transportation costs if the delivery mode chosen exceeds the required delivery timeframe. Constraint (10) indicates the optimal shipping modes to deliver the DLR inventory. When a shipping mode is chosen and $Z_{i,m,d,c}$=1, the constraint on $X_{i,m,d,c}$ is relaxed to be less than a large scalar. However, when $Z_{i,m,d,c}$=0, the constraint

restricts $X_{i,m,d,c}$ to zero and that shipping mode is not considered valid. Constraint (14) is a binary variable that assumes the value of one for each depot SIP chooses to use and a value of zero otherwise.

Alternatively, the Basic Model can also be extended to include the cost of exceeding the RDD by adding an additional cost to any $X_{i,m,d,c}$ variable where $DELTIME_{c,m,d}$ exceeds $RDD_{i,c}$. While SIP penalizes each shipment regardless of quantity, this alternative model assigns a penalty dependent on the quantity shipped.

F. DATA

This section discusses the composition of the data, selection of a test set, and the data assumptions made to implement SIP.

1. Composition of Data

NAVICP has provided a Microsoft Access database covering the period October 01, 2002 through March 31, 2004. The database consists of 92,662 uniquely identifiable NSN accounting for over 2 million requisitions. The requisitions in the NAVICP database have many record type fields that provide the means to construct a test set for SIP implementation. Two main record type fields are Type Transaction Code and the COG. A Type Transaction Code is synonymous with a Document Identifier (DI) that specifically identifies each type of requisition (i.e., passing action, status transaction, receipt, and adjustment). Table 4.1 provides a breakdown by DI of all requisitions in the NAVICP database.

DI	# of Requisitions	% of Total Requisitions	DI	# of Requisitions	% of Total Requisitions
A21	5,088	0.25%	D6A	38,127	1.85%
A22	1	0.00%	D6B	6,922	0.34%
A24	5	0.00%	D6C	59	0.00%
A25	27	0.00%	D6D	41	0.00%
A2A	180,032	8.73%	D6E	5	0.00%
A2D	128	0.01%	D6H	32	0.00%
A2E	8,854	0.43%	D6J	1,234	0.06%
A51	169,730	8.23%	D6K	616,704	29.89%
A52	2	0.00%	D6L	83	0.00%
A54	163	0.01%	D6M	230,755	11.18%
A55	5,007	0.24%	D6N	51	0.00%
A5A	566,785	27.47%	D6Q	2	0.00%
A5B	3	0.00%	D6R	303	0.01%
A5D	889	0.04%	D6T	6	0.00%
A5E	68,250	3.31%	D6U	1,013	0.05%
A5J	41,944	2.03%	D6V	34	0.00%
D4M	3,768	0.18%	D6Z	1,678	0.08%
D4S	71,186	3.45%	DAA	2,139	0.10%
D4U	107	0.01%	DAC	5,173	0.25%
D4V	7	0.00%	ZWT	36,675	1.78%
D4Z	183	0.01%			
Total Requisitions					2,063,195

Table 4.1: Document Identifiers

This table presents the document identifiers (DIs) in the NAVICP database for each requisition occurring from October 01, 2002 through March 31, 2004. DI A5A identifies a materiel release order for a domestic shipment. The table shows there were 566,785 such transactions conducted during this period.

The other record type field of interest is the COG. The NAVICP database has 50 distinct COGs used to requisition materiel during the aforementioned timeframe. Table 4.2 presents the 25 most commonly used COGs identified in the NAVICP database. These 25 COGs account for 96.4% of all the transactions occurring from October 01, 2002 through March 31, 2004.

COG	# of Requisitions	% of Total Resiquisitions
7R	1,325,439	64.24%
7H	243,696	11.81%
1R	150,114	7.28%
1H	137,253	6.65%
7G	68,853	3.34%
7E	23,505	1.14%
6K	12,606	0.61%
3H	9,993	0.48%
7Z	7,054	0.34%
4Z	2,874	0.14%
6D	1,780	0.09%
6R	1,224	0.06%
9G	977	0.05%
3Z	657	0.03%
0R	618	0.03%
9Z	392	0.02%
3N	341	0.02%
0O	297	0.01%
0Q	291	0.01%
9N	244	0.01%
9C	232	0.01%
9W	196	0.01%
6B	191	0.01%
9J	144	0.01%
9F	33	0.00%
Total	1,989,004	96.40%
Grand Total	2,063,195	100.00%

Table 4.2: COG

This table presents the 25 most commonly used COGs to requisition materiel from October 31, 2002 through March 31, 2004. A 7R COG refers to aviation DLRs, and accounts for 64% of the total items ordered during this 18-month period.

2. Selection of Test Data

A sample of the NAVICP database is used to test the SIP model and provide a basis to conduct a comparative analysis of the results. This sample hereto is called the ‘test set’. The test set consists of requisitions from the NAVICP database using the Transaction Type Code to identify all materiel release orders submitted for domestic shipment. These items are identifiable using the following DIs: A5A, A5B, A5D, and A5E (see Table 4.1). This reduces the possible data in the database to 635,927

requisitions consisting of 48,927 unique NIINs. Use of the COG enables selection of only DLR items from this reduced database. The commonly used COGs to identify DLR items are 7E, 7G, 7H, 7R, and 7Z. This further reduces the database to 433,830 requisitions consisting of 23,992 unique DLR NIINs. From this new database, analysis identifies the one hundred repairable NIINs with the highest number of demands and an additional one hundred repairable NIINs with the largest transportation cost. Table 4.3 and 4.4 shows the repairable NIINs resulting from this selection process. Combining these two selections results in a test-set containing 78,909 requisitions consisting of 176 unique NIINs. As seen from Tables 4.3–4.4 these 176 repairable NIINs represent 17% of total demand and 38% of all transportation costs.

NIIN	% Of Total Requisitions	NIIN	% Of Total Requisitions	NIIN	% Of Total Requisitions	NIIN	% Of Total Requisitions
014948719	9.66%	011861672	0.97%	011397177	0.70%	001174118	0.59%
011424304	3.11%	013453117	0.97%	012423695	0.69%	014144946	0.59%
011412735	2.90%	013513373	0.90%	011144422	0.68%	014082090	0.59%
013206854	2.43%	014960533	0.88%	011629449	0.68%	009639444	0.58%
014494496	2.37%	010401531	0.86%	013571941	0.68%	010471348	0.58%
011664886	2.15%	013163474	0.85%	011311435	0.68%	011911817	0.58%
014145895	2.11%	013164973	0.85%	001655838	0.67%	013986528	0.58%
011407620	2.07%	011424347	0.84%	013931180	0.66%	013693370	0.58%
013437026	1.90%	012423760	0.84%	012374089	0.66%	012965754	0.57%
013151717	1.88%	010491153	0.83%	011771963	0.66%	013010814	0.57%
014653534	1.68%	010625846	0.78%	014980241	0.66%	011407627	0.57%
001105521	1.57%	010041804	0.77%	014106751	0.65%	008871969	0.57%
001592298	1.54%	000203211	0.76%	011542869	0.65%	013988561	0.57%
013538344	1.45%	000828666	0.76%	011629391	0.64%	011240903	0.56%
001113645	1.42%	013987155	0.76%	014585910	0.64%	013910502	0.56%
001491319	1.37%	012567691	0.76%	011614443	0.64%	011589679	0.56%
013432609	1.32%	012653659	0.75%	012016313	0.64%	000309552	0.56%
014743711	1.23%	012019481	0.75%	011325908	0.63%	014763224	0.56%
012185553	1.23%	014673559	0.74%	011314730	0.61%	001174629	0.56%
012138145	1.13%	014254920	0.73%	014421596	0.61%	014638057	0.55%
001677675	1.12%	012711063	0.73%	998919977	0.61%	010193892	0.55%
011204885	1.08%	011258904	0.72%	004383487	0.60%	011569309	0.55%
014556975	1.02%	011629429	0.72%	011987705	0.60%	011635406	0.55%
014673556	0.99%	012029228	0.71%	011790560	0.59%	013416041	0.55%
014871910	0.99%	014456362	0.71%	012265321	0.59%	011758470	0.55%
		Total		72,299			
		Database Total		433,830			

Table 4.3: 100 High Demand NIINs

This table provides the 100 NIINs with the greatest demand during the 18-month observation timeframe. For example, NIIN 01-494-8719 identifies an Aircraft Turbine Nozzle Segment, which has had 6,891 (9.66%) requisitions placed during the observation period.

NIIN	Total Transportation Costs	NIIN	Total Transportation Costs	NIIN	Total Transportation Costs	NIIN	Total Transportation Costs
014651509	8.13%	014254919	0.92%	013896529	0.59%	002019809	0.47%
001688769	7.06%	012866684	0.89%	014650844	0.59%	014421596	0.46%
014140187	4.63%	010959170	0.85%	014002184	0.59%	014080379	0.46%
012225163	3.66%	012240484	0.84%	014353715	0.59%	014638057	0.45%
000309552	3.32%	014115215	0.80%	011190647	0.58%	014555217	0.45%
012204747	3.25%	008871944	0.78%	011473037	0.57%	014145895	0.45%
011589679	2.91%	001737439	0.78%	014256322	0.56%	014148410	0.45%
014437394	2.51%	013205055	0.78%	013988561	0.55%	001491319	0.43%
014660084	1.82%	002052253	0.77%	010687755	0.55%	014086574	0.41%
012364761	1.77%	014353720	0.75%	013432609	0.55%	012027264	0.41%
013960647	1.68%	001489231	0.72%	014131049	0.55%	001174629	0.41%
013437026	1.61%	013174521	0.71%	002097984	0.53%	011932157	0.40%
011917057	1.59%	001655838	0.69%	014367087	0.53%	014388413	0.40%
013664970	1.58%	001796510	0.68%	013949231	0.52%	012743443	0.40%
013205057	1.44%	011412735	0.68%	012866685	0.52%	012653659	0.40%
013163474	1.35%	012643928	0.65%	014382596	0.52%	012274925	0.39%
014245924	1.32%	013841454	0.65%	014077972	0.51%	011290138	0.39%
001592298	1.26%	012238403	0.64%	013584354	0.51%	014091097	0.39%
011428815	1.17%	013000940	0.64%	012429714	0.51%	011506731	0.39%
012965754	1.11%	013887479	0.63%	014252532	0.50%	010667325	0.38%
014871910	1.10%	011861672	0.63%	012743482	0.50%	011402298	0.38%
004028651	1.07%	010577834	0.63%	013513373	0.50%	009844752	0.38%
013987155	1.03%	012374089	0.62%	013693370	0.50%	011771963	0.38%
013947572	0.99%	012016313	0.62%	014650843	0.49%	011258013	0.37%
013506640	0.95%	013189077	0.61%	012743433	0.49%	010537272	0.37%
		Total Cost		$	4,287,627.63		
		Database Total Cost		$	11,142,406.39		

Table 4.4: 100 NIINs with the Highest Transportation Costs

This table provides the 100 NIINs with the greatest transportation costs during the 18-month observation timeframe. For example, NIIN 01-465-1509 identifies an Aircraft Turbine Nozzle Segment, which has had 302,616.23 dollars (8.13% of database total) in requisitions placed during the observation period.

3. Data Assumptions

Assumptions were made in order to make the data more manageable and shorten computer computational time. An overview of these assumptions follows.

a. Aggregation of Customers

Every requisition submitted to the supply system contains a customer identifier. These identifiers are called DODAACs, which is a Department of Defense Acquisition Address Code. The DODAAC is a uniform way of identifying a customers' organization and address and is composed of a six-digit (alphanumeric) code. Using the DODAACs in the test set, 615 customers where identified and their corresponding zip

code was manually obtained using the Defense Activity Addressing System (DAAS) [DAAS 2005]. This study aggregates these customers using an aggregation scheme from Holmes [1994]. The aggregation scheme clusters customers into a geographic region using the first three digits of their shipping zip code. This aggregation creates 86 customer regions within the continental United States. Predictably, most of the demand (over 90 percent) is concentrated in the homeports of ships, submarines and aircraft and consists of just 5 customer regions (as shown in Table 4.5).

Customer Region	Zip	# of Requisitions	% of Total Requisitions
C18	VA 23511	37,946	48.09%
C75	CA 92123	32,315	40.95%
C11	PA 19111	2,524	3.20%
C14	MD 20670	1,210	1.53%
C32	FL 32508	1,112	1.41%
Total		75,107	95.18%
Total Requisitions		78,909	100.00%

Table 4.5: Top 5 Customer Regions

This table displays the top five customer regions that make up 95% of NAVICP's DLR requisitions from October 1, 2002 to March 31, 2004.

b. Transportation Costs

Analysis of the NAVICP database shows that many of the requisitions for the same DLR going to the same customer from the same distribution depot can have different transportation costs. Table 4.6 shows an example of this analysis. One of the major reasons for the differing transportation costs is attributable to the shipping and packaging methods employed. For example, if the DLR is placed on a pallet with other inventory the shipping cost is averaged. However, if the DLR is packaged individually the transportation costs depend on the size and weight of the DLR and the shipping container (container sizes vary). This results in a DLR with the same basic requisition characteristics (originator, weight, ship to customer, and shipping mode) having multiple transportation costs. The intent of the author was to take the database transportation cost and extrapolate the shipping costs for each mode of shipment relative to the weight of the DLR shipped. Because of the varying transportation costs in the database, the shipping

costs built into SIP come from DLA estimated costs for fiscal year 2004 [DeVito 2004]. Table 4.7 lists the estimated cost for each shipping mode.

NIIN	Distribution Depot	Customer State	Ipd	Qty	WT	Ship Mode	Trans Cost
001270242	Jacksonville, FL	CA	05	1	142	Q	$163.15
001270242	Jacksonville, FL	CA	05	1	142	Q	$83.95
001270242	Jacksonville, FL	CA	05	1	142	Q	$63.45

Table 4.6: Erratic Transportation Costs

This table gives an example of the varying transportation costs for NIIN 00-127-0242, an Arresting Stinger costing $21,671.00, weighing 142 lbs and shipped via modes Q (Commercial Air Freight) from Distribution Depot Jacksonville, FL to USS LINCOLN (CVN 72) in San Diego, CA.

Mode	Description	Cost
J	Air, Small Package Carrier	$ 1.06 /lb-mile
9	Local Delivery by Commercial Truck	$ 1.00 ea
Q	Commercial Air Freight	$ 0.79 /lb-mile
I	Government Truck	$ 1.24 ea
5	Surface Small Package Carrier	$ 0.12 /lb-mile
B	Motor, Less Than Truckload	$ 0.24 /lb-mile
S	Scheduled Truck	$ 0.09 /lb-mile
A	Motor, Truckload	$ 0.12 /lb-mile

Table 4.7: SIP Transportation Costs

This table shows the shipping cost for each mode of transportation used in the SIP model. As seen, Government Truck incurs a fixed local shipping cost for deliveries within 60 miles of the distribution depot.

c. *Shipping Modes*

An analysis of the NAVICP database suggests that approximately 99.75% of the DLR inventory is shipped utilizing the eight modes of transportation shown in Table 4.8. It appears that mode J-Air Small Package Carrier (50%), is the most highly used mode of shipping DLR items to customers. SIP uses these top eight modes of transportation as a basis in computing transportation costs. Table 4.9 shows the distance-to-time rule used to establish each of the eight modes chosen to populate SIP. These delivery times were computed using the distance from each depot to customer pair and the travel rules established in Table 4.9. For example, the distance from Distribution Depot Norfolk, VA to a customer in GA is 510 miles, using Table 4.9 this equates to a delivery time of two days for modes 5, 9, A, B, I, and S.

Mode	Description	# of Shipments	% of Total Shippments
J	Air, Small Package Carrier	39,363	50.01%
9	Local Delivery by Commercial Truck	22,031	27.99%
Q	Commercial Air Freight	5,973	7.59%
I	Government Truck	3,301	4.19%
5	Surface Small Package Carrier	2,807	3.57%
B	Motor, Less Than Truckload	2,664	3.38%
S	Scheduled Truck	1,471	1.87%
A	Motor, Truckload	1,101	1.40%
Total		78,711	99.75%

Table 4.8: Shipping Modes

This table shows the top eight shipping modes used to deliver DLR inventory. It appears mode J, Air Small Package Carrier, is used 50% of the time to ship materiel from October 31, 2002 through March 31, 2004.

Mode	Description	Delivery Time
J	Air, Small Package Carrier	1 Day
9	Local Delivery by Commercial Truck	1 Day
Q	Commercial Air Freight	1 Day
I	Government Truck	1 Day = 350 mi
5	Surface Small Package Carrier	1 Day = 350 mi
B	Motor, Less Than Truckload	1 Day = 350 mi
S	Scheduled Truck	1 Day = 350 mi
A	Motor, Truckload	1 Day = 350 mi

Table 4.9: Distance-to-Time Rule

This table displays the distance-to-time rule used to establish the delivery time for each shipping mode.

d. Required Delivery Time

SIP uses time as a constraint to maintain a certain level of customer service. The NAVICP database provides the Issue Priority Designators (IPDs) of each DLR requisition to aid the IM in determining the appropriate urgency of need for the customer requisitioning the item. Table 4.10 shows the IPD matrix, which is used by UICP as a standard to determine delivery time. From the matrix, the IPD can be derived using the Force Activity Designator (FAD) and Urgency of Need (UND) of the requisition. Table 4.11 provides a breakdown of the requisitions in the database by IPD.

Urgency of Need Designator (UND)	Force Activity Designators (FAD)				
	I	II	III	IV	V
	Issue Priority Designator				
A Unabld to Perform	01	02	03	07	08
B Performance Impaired	04	05	06	09	10
C Routine	11	12	13	14	15

Table 4.10: Issue Priority Designator Matrix

This table shows the issue priority designators used by UICP and the item manager to determine the customer's urgency of need for the requisitioned materiel. For example, FAD II with UND A (IPD 02) means the requestor is deploying within 24 hours and the part is urgently needed to repair an important weapon system.

Ipd	# of Requisitons	% of Total Requisitions
01	339	0.25%
02	14,705	10.94%
03	35,990	26.77%
04	748	0.56%
05	17,662	13.14%
06	61,824	45.99%
07	335	0.25%
08	400	0.30%
09	125	0.09%
10	34	0.03%
11	338	0.25%
12	261	0.19%
13	1,439	1.07%
14	65	0.05%
15	174	0.13%
Total	134,439	100.00%

Table 4.11: Issue Priority Designators

This table shows the breakdown by IPD of requisitions placed from October 01, 2002 to March 31, 2004 for DLRs.

The time standards currently programmed into UICP use a Uniform Materiel Movement and Issue Priority System (UMMIPS) matrix [DOD 2003] as shown in Table 4.12. UMMIPS ensures that materiel requisitions are processed according to military importance and urgency of need. UMMIPS establishes the base line upon which the issue priority designators in the test set where converted into RDDs. This thesis uses the total order-to-receipt time for the shipment of materiel within the continental United

States (CONUS) to institute delivery time standards in SIP. For example requisitions with priority designator 01-03 has 3.5 days order-to-receipt time, see Table 4.12. For requisitions with priority designators 04-16, order-to-receipt time depends on the urgency of need identified by the customer. For more information on the deformation of RDDs see [NAVSUP 2004].

UMMIPS TIME STANDARD IN CALENDAR DAYS																
	PD 01-03 ALL RDD's						PD 04-08, RDD 777 or PD 04-15 W/RDD 444, 555, 777					PD 04-15 W/Blank RDD or RDD >8 days after Reqn Date				
	TP 1 AREA						TP 2 AREA					TP 3 AREA				
PIPELINE SEGMENT	CONUS	A	B	C	D	EXP	CONUS	A	B	C	D	CONUS	A	B	C	D
A. Requisition Submission Time	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	1	1	1	1	1
B. ICP Processing Time	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	1	1	1	1	1
C. Storage Site (or Base) Processing, Packaging and Transportation Hold Time	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3	3
D. Storage Site to CCP Transportation Time	N/A	1	1	1	1	N/A	N/A	3	3	3	3	N/A	7	7	7	7
E. CCP Processing Time	N/A	.5	.5	.5	1	N/A	N/A	1	1	1	1	N/A	5	5	5	10
F. Conus In-Transit Time	1	1	1	1	1	N/A	4	2.5	2.5	2.5	2.5	9	7	7	7	7
G. POE Processing and Hold Time	N/A	1	1	1	2	N/A	N/A	2	2	2	3	N/A	5	5	5	10
H. In-Transit to Theater Time	N/A	1	1	1	1.5	3	N/A	1	1	1	1.5	N/A	5	12	19	27
I. POD Processing Time	N/A	.5	.5	.5	1	N/A	N/A	.5	.5	.5	1	N/A	3	3	3	5
J. In-Transit, Within-Theater Time	N/A	1	1	1	1	1	N/A	1	1	1	1	N/A	5	5	5	5
K. Receipt Take-Up Time	.5	.5	.5	.5	.5	.5	1	1	1	1	1	2	2	2	2	2
Total Order-to-Receipt Time	3.5	8.5	8.5	8.5	11	6.5	7	14	14	14	16	16	44	51	58	78

Table 4.12: UMMIPS Time Standards Matrix

This table shows the established UMMIPS standards for normal requisition processing times for items that are stocked and ready for issue. For example, a requisition with a priority designator of 01 - 03 falls into TP 1 area and has a 3.5 day order-to-receipt time standard.

e. Initial Stock Amounts

The objective of the SIP model is to optimally locate DLR inventory within DLA's established distribution network. A particular issue that arises in trying to accomplish this task deals with basing the positioning decision solely on the historical storage locations captured in the NAVICP database. When trying to determine future inventory positions based on past storage locations, the model would be limited to only choosing from those locations that have historically stored the materiel. To enable SIP to

widen its scope and calculate which depots to place materiel amongst all in the network requires the use of a parameter, see Eq (7). By employing a parameter, SIP is able to populate each distribution depot with a predetermined amount of stock and then calculate the best locations to position the inventory. In the computational study, we set the amount of stock to be sufficiently large so we are not restrictive. Table 4.13 shows the quantity of DLR materiel previously stored in each distribution depot.

The SIP model also allows the user to decide how many depot locations SIP should use to determine the optimal stock locations, see Eq (11). This aids in 'what-if' analysis and assist NAVICP in determining the cost benefits associated with limiting or expanding the number of locations to place inventory.

Depot ID	Name	# of Total Requisitions	% of Total Requisitions
JF	Defense Distribution Depot Jacksonville, FL	38,129	48.32%
DC	Defense Distribution Depot San Diego, CA	23,190	29.39%
CN	Defense Distribution Depot Cherry Point, NC	9,563	12.12%
NV	Defense Distribution Depot Norfolk, VA	3,171	4.02%
OO	Defense Distribution Depot Oklahoma City, OK	1,352	1.71%
TP	Defense Distribution Depot Tobyhanna, PA	1,349	1.71%
WG	Defense Distribution Depot Warner Robbins, GA	616	0.78%
J2	Tracy Facility Code	454	0.58%
O2	Defense Hill Facility	430	0.54%
S2	Defense New Cumberland Facility	417	0.53%
AP	Pearl Depot	99	0.13%
C1	Defense Distribution Depot Corpus Christi, TX	62	0.08%
PW	Defense Distribution Depot Puget Sound, WA	56	0.07%
RT	Defense Distribution Depot Red River, TX	18	0.02%
BC	Defense Distribution Depot Barstow, CA	3	0.00%
Total Requisitions		78,909	100.00%

Table 4.13: Current DLR Storage Locations

This table shows the quantity of DLR inventory stored in DLA distribution depots from October 31, 2002 to March 31, 2004. The remaining ten depots were not used to store any repairable items during this period.

G. COMPUTATIONAL EXPERIENCE

The SIP model is run on a Pentium IV personal computer operating at 2.4 GHz with 1 GB of RAM. SIP takes between 3 to 4 seconds to generate the problem set and another 3 to 4 seconds to obtain an optimal solution per NIIN. The model consists of

21,778 equations, 32,527 single variables, 10,854 discrete variables, and 86,725 non-zero elements. Initially, the penalty, *PEN*=1M dollars per day for all customers *c*.

If money and storage were not an issue, inventory would be located in every customer location where there is a requisition for that item. Due to recent budget constraints and the limited number and locations of distribution depots in the DLA network this "stock everywhere" policy is not feasible. Therefore the first question SIP addresses is how many storage locations should be used to store NAVICP's DLR inventory. To answer this question SIP was run using variations on the number of depots to stock materiel. The next question SIP addresses (for each individual NIIN) is which depots within DLA's distribution network should inventory be located to reduce transportation costs and customer wait time. The last question SIP answers pertains to how much of each item to place in each of the depots identified in the previous two questions. To address these last two questions additional runs where made to allow SIP to strategically position the DLR inventory within DLA's distribution network. The $STOCK_{i,d}$ parameter Eq. (7) was set to 100,000 items to provide a sufficiently large amount of materiel in each distribution depot. This also enables SIP to choose between all the depots in determining which depot to utilize and position DLR items.

H. MODEL RESULTS

Examination of different values for SIP's $MAXDEPOT_i$ parameter Eq. (11) provides insight in determining potential cost saving from varying the number of storage locations to position DLR inventory. Figure 4.1 shows the results of these runs. This figure shows that a maximum of five locations for each NIIN provide the greatest reduction in transportation cost. No further reduction in cost is obtainable when distributing inventory over more depots. Figure 4.1 also shows that the transportation cost increases significantly if each DLR item is only stored at one or two distribution depots. The cases with two or more depots have no delays, i.e., all deliveries are within RDD. For one depot, up to a half day is observed for some items. It is unknown how much delay was experienced historically.

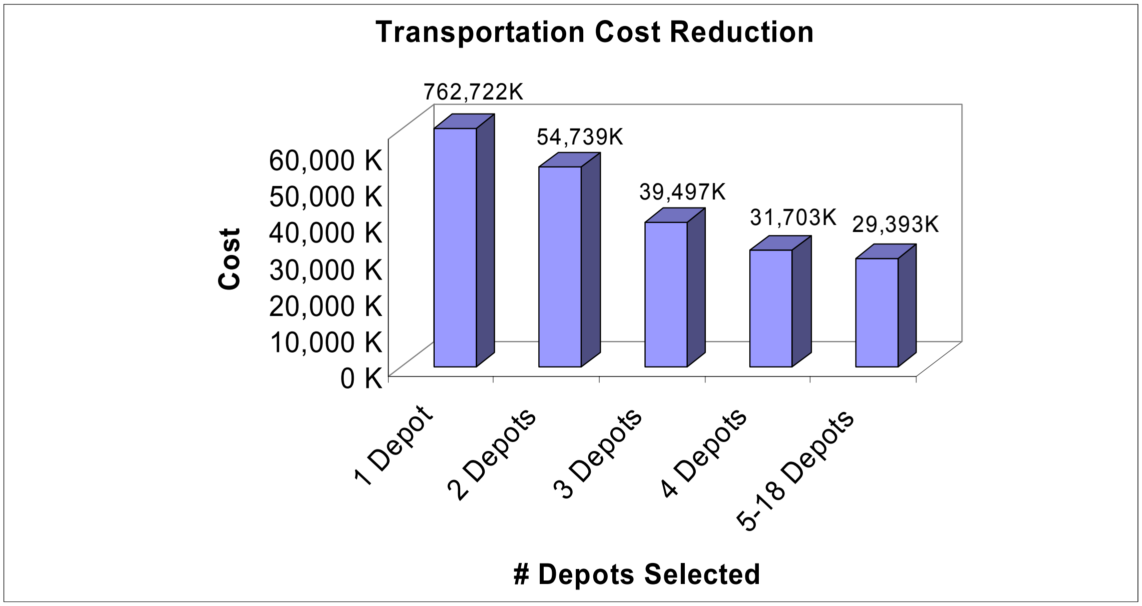

Figure 4.1: Transportation Cost versus Number of Depots

This figure shows the transportation cost associated with varying the number of distribution depots for the 176 DLR items in the SIP test set. UICP's transportation cost for the same 176 DLR items is $11.9B. The table suggests transportation costs are minimized using five distribution depots to store inventory. *Note Figure not drawn to scale.

Next, the historical transactions provided by NAVICP, is compared to the recommendations from SIP. This analysis uses the test set data to determine the depot where inventory is located, the location of the customers requisitioning the items, and the modes of shipment utilized. For the historical transactions, the customer locations are aggregated according to the aggregation tables within SIP. Also the distance table instantiated in SIP is used to compute the actual distance from the depot to the customer for historical transactions. These modifications were necessary to establish a baseline to conduct the comparison of the recommendations from UICP to those from SIP. A cost comparative analysis of the 176 DLR NIINs with the highest shipping cost and highest demand is available for review in the Appendix. The Appendix shows the costs of using the UICP recommended storage locations was $11B. The Appendix also shows that by using five storage locations as recommended by SIP, transportation costs can be reduced to $29M. This cost difference is the result of using DLAs new synchronized and

scheduled truck system and better repairable inventory locations, but does not include costs to ship materiel from the repair facility to the distribution depot.

Two examples of this comparative analysis are given in Table 4.14 and Table 4.15 using a DLR with a high shipping cost and a DLR with a high demanded rate, respectively. Table 4.14 shows the results of looking at a connector adaptor (NIIN 01-414-0187) which experienced a 547K dollar shipping cost using the UICP positioning policy. Repair of this connector takes place at a Naval Air Depot Norfolk, VA. In accordance with NAVICP current positioning policy once repair is complete, the repairable is shipped to the distribution depot in VA because it is the closest distribution depot. The cost to ship this connector is only $1.24 because is it considered a local delivery (within 60 miles). Using SIP to determine the optimal location using one, two, and three depots shows a reduction in cost of more than 480K dollars. Here the cost of transporting materiel from the repair facility to the distribution depot is included. We note that the cost of using three depots is larger than using one and two because of the larger repair facility-to-depot costs.

UICP	Depot Name	Depot Zip	QTY	Customer Zip	Ship Mode	DIST	Shipping Cost	TRANSCOST
	NV	VA 23511	1	VA 23511	9	1 mi	$ 1.24	$ 1.24
	NV	VA 23511	1	SC 29405	B	351 mi	$ 0.24	$ 11.4 K
	NV	VA 23511	1	SC 29405	Q	351 mi	$ 0.79	$ 37.5 K
	NV	VA 23511	2	CA 92123	Q	2332 mi	$ 0.79	$ 497.4 K
	Transportation cost from Repair Facility in VA to depot NV							$ 1.24
	Total Cost Using UICP (NAVICP Transaction Database) with the Shipping Cost Listed							$ 547.5 K
1 Depot	NV	VA 23511	1	VA 23511	9	1 mi	$ 1.24	$ 1.24
	NV	VA 23511	2	SC 29405	S	351 mi	$ 0.09	$ 8.5 K
	NV	VA 23511	2	CA 92123	S	2332 mi	$ 0.09	$ 56.7 K
	Transportation cost from Repair Facility in VA to depot NV							$ 1.24
	Total Cost Using 1 Depot computed by SIP with the Shipping Cost Listed							$ 65.2 K
2 Depots	NV	VA 23511	1	VA 23511	9	1 mi	$ 1.24	$ 1.24
	NV	VA 23511	2	SC 29405	S	351 mi	$ 0.09	$ 8.5 K
	DC	CA 92136	2	CA 92123	S	9 mi	$ 0.09	$ 0.2 K
	Transportation cost from Repair Facility in VA to depots NV and DC							$ 56.7 K
	Total Cost Using 2 Depots computed by SIP with the Shipping Cost Listed							$ 65.5 K
3 Depots	NV	VA 23511	1	VA 23511	9	1 mi	$ 1.24	$ 1.24
	JF	FL 32212	2	SC 29405	S	208 mi	$ 0.09	$ 5.0 K
	DC	CA 92136	2	CA 92123	S	9 mi	$ 0.09	$ 0.2 K
	Transportation cost from Repair Facility in VA to depots NV, JF, and DC							$ 70.3 K
	Total Cost Using 3 Depots computed by SIP with the Shipping Cost Listed							$ 75.6 K

Table 4.14: Transportation Cost Comparison for NIIN 01-414-0187

This table displays the results of a cost comparison for a connector adaptor that weighs 135 lbs. The comparison uses UICP recommended storage locations and SIP recommendations. This table shows NIIN 01-414-0187 could be optimally located in one to two depots and reduce transportation costs by over 480K dollars. The magnitude of savings is by using the new shipping resulting in a reduction from $547.5K to $75.6K. No better solution was given by varying the number of depot from 4 to 18.

Table 4.15 shows the results of looking at a nozzle segment for a gas turbine in an aircraft engine that has a monthly demand rate 1,130 requisitions. This DLR is repaired at Naval Air Depot Jacksonville and once the item has completed repair, it is relocated to Defense Distribution Depot Jacksonville, FL for storage. Comparing the results of strategically locating this DLR in the three depots as recommended by SIP instead of the one recommended by UIPC results in over a 608M dollar reduction in transportation costs. In this case there is a reduction in costs going from one, to two, to three depots.

UICP	Depot Name	Depot Zip	QTY	Customer Zip	Ship Mode	DIST	Shipping Cost	TRANSCOST
	JF	FL 32212	243	VA 23511	5	558 mi	$ 0.12	$ 2,035.4 K
	JF	FL 32212	199	VA 23511	B	558 mi	$ 0.24	$ 3,333.6 K
	JF	FL 32212	4662	VA 23511	J	558 mi	$ 1.06	$ 344,932.1 K
	JF	FL 32212	573	VA 23511	Q	558 mi	$ 0.79	$ 31,596.4 K
	JF	FL 32212	10	FL 32508	J	333 mi	$ 1.06	$ 441.8 K
	JF	FL 32212	18	CA 92123	5	2096 mi	$ 0.12	$ 565.9 K
	JF	FL 32212	31	CA 92123	9	2096 mi	$ 0.00	$ 8,122.4 K
	JF	FL 32212	60	CA 92123	B	2096 mi	$ 0.24	$ 3,773.0 K
	JF	FL 32212	788	CA 92123	J	2096 mi	$ 1.06	$ 218,853.8 K
	JF	FL 32212	291	CA 92123	Q	2096 mi	$ 0.79	$ 60,234.1 K
	Transportation cost from Repair Facility in FL to depot JF							$ 1.24
	Total Cost Using UICP (NAVICP Transaction Database) with the Shipping Cost Listed							$ 673,888.4 K
1 Depot	NV	VA 23511	5677	VA 23511	9	1 mi	$ 1.24	$ 1.24
	NV	VA 23511	10	FL 32508	S	777 mi	$ 0.09	$ 87.4 K
	NV	VA 23511	1188	CA 92123	S	2332 mi	$ 0.09	$ 31,167.2 K
	Transportation cost from Repair Facility in FL to depot NV							$ 43,242.9 K
	Total Cost Using 1 Depot computed by SIP with the Shipping Cost Listed							$ 74,498.7 K
2 Depots	NV	VA 23511	5677	VA 23511	9	1 mi	$ 1.24	$ 1.24
	NV	VA 23511	10	FL 32508	S	777 mi	$ 0.09	$ 87.5 K
	DC	CA 92136	1188	CA 92123	S	9 mi	$ 0.09	$ 113.6 K
	Transportation cost from Repair Facility in FL to depots NV and DC							$ 65,633.9 K
	Total Cost Using 2 Depots computed by SIP with the Shipping Cost Listed							$ 65,836.2 K
3 Depots	NV	VA 23511	5677	VA 23511	9	1 mi	$ 1.24	$ 1.24
	WG	GA 31704	10	FL 32925	S	208 mi	$ 0.09	$ 23.4 K
	DC	CA 92136	1188	CA 92123	S	9 mi	$ 0.09	$ 113.6 K
	Transportation cost from Repair Facility in FL to depots NV, WG, and DC							$ 65,586.8 K
	Total Cost Using 3 Depots computed by SIP with the Shipping Cost Listed							$ 65,725.1 K

Table 4.15: Transportation Cost Comparison for NIIN 01-494-8719

This table displays the results of a cost comparison for a nozzle segment for a gas turbine in an aircraft engine that weighs 125 lbs. The comparison uses UICP recommended storage locations and SIP recommendations. This table shows NIIN 01-494-8719 could be optimally located in three depots and reduce transportation costs by over 608M dollars. No better solution was given by varying the number of depot from 4 to 18.

These two examples where chosen because they represent the two DLRs with the highest transportation costs and the highest demand in the test set, respectively. These two DLRs are also examples of NAVICP's current positioning policy of placing repaired inventory in the distribution depot closest to the repair facility. The result of using this policy requires NAVICP to use more expensive shipping modes to ensure the materiel reaches the customer by the required delivery date. This ultimately increases transportation cost.

For high volume items it is always cost effective to position materiel in distribution depots with high demand concentrations. But, for low volume materiel it may not be cost effective to store repairable materiel in more than one or two distribution depots (e.g., one on each coast). This reduces the need to use expensive shipping modes when stock is depleted at a local depot.

Both of these tables show that by strategically placing these DLRs and using DLA's scheduled truck system to deliver the DLR to the distribution depot after repair and when filling a new requisition, NAVICP can achieve substantial reductions in transportation costs. The example from Table 4.14 and 4.15 equate to an average cost savings of more than 500M dollars.

When the need arises to expedite the shipment of DLRs, the Item Manager might want to know when it is beneficial to switch to a faster shipment method. SIP's *PEN* parameter in the objective function is used to charge a penalty for exceeding the RDD set by the customer. This penalty goes into effect for each delayed depot and mode of shipment no matter what quantity is being shipped. This penalty can be useful in analyzing various "what if" scenarios. For example, if the Item Manager is concerned with maintaining RDD standards, then a large penalty can be used to determine the best mode of shipment to meet that date. If the Item Manager allows leeway in the RDD, then a small penalty can be applied to allow all methods of shipment. The penalty can also be used to reflect the actual cost of delay for the customer in reducing their readiness level and the affect this delay can have on their ability to conduct their assigned mission. Table 4.16 and 4.17 expands upon the data from Table 4.15 using the same nozzle segment to show various scenarios where the *PEN* penalty has been varied as well as cases with reduced RDD.

		SIP Results Using 1 Depot = NV											
		PEN =100				*PEN* = 100,000				*PEN* = 1,000,000			
	Customer	Mode	RDD	Delay Time	Cost	Mode	RDD	Time	Cost	Mode	RDD	Delay Time	Cost
RDD	VA 23511	9	9	0	$31,254.7 K	9	9	0	$31,304.6 K	9	9	0	$31,754.6 K
	FL 32508	S	4	0		S	4	0		S	4	0	
	CA 92123	S	5.5	0.5		S	5.5	0.5		S	5.5	0.5	
RDD-1	VA 23511	9	8	0	$31,254.8 K	9	8	0	$31,404.6 K	9	8	0	$32,754.6 K
	FL 32508	S	3	0		S	3	0		S	3	0	
	CA 92123	S	4.5	1.5		S	4.5	1.5		S	4.5	1.5	
RDD-2	VA 23511	9	7	0	$31,255.0 K	9	7	0	$31,604.6 K	9	7	0	$34,434.9 K
	FL 32508	S	2	1		S	2	1		Q	2	0	
	CA 92123	S	3.5	2.5		S	3.5	2.5		S	3.5	2.5	
RDD-3	VA 23511	9	6	0	$31,255.2 K	9	6	0	$31,804.6 K	9	6	0	$35,434.9 K
	FL 32508	S	1	2		S	1	2		Q	1	0	
	CA 92123	S	2.5	3.5		S	2.5	3.5		S	2.5	3.5	
RDD-4	VA 23511	9	5	0	$31,255.3 K	9	5	0	$31,904.6 K	9	5	0	$36,434.9 K
	FL 32508	S	1	2		S	1	2		Q	1	0	
	CA 92123	S	1.5	4.5		S	1.5	4.5		S	1.5	4.5	

Table 4.16: Effects of Varying *PEN* Penalty for One Depot

This table shows the effects of storing a nozzle segment in one distribution depot while setting the *PEN* penalty to 100, 100K, and 1M respectively. In each RDD row the customers RDD is reduced by one day and the extra time SIP borrows for exceeding the RDD (Delay Time) is charged a penalty until the charge is higher than the cost involved in choosing another mode of transportation.

Table 4.16 shows that the RDD is exceeded when the *PEN* penalty parameter is not set high enough to increase the transportation costs above the cost involved in choosing an alternative shipping mode. Looking at the Delay Time column for *PEN*=100 dollars per day and the row labeled RDD, shows a delay of half a day using a scheduled truck to ship the materiel from Virginia (Depot NV) to California. The result is the $50 penalty applied to the total transportation costs. Whereas, looking at the Delay Time column with the row labeled RDD-4 (reducing the RDD by 4 days) shows multiple shipping delays. There is a delay of two days in shipping the materiel via scheduled truck from Virginia (Depot NV) to Florida and a four and a half day delay in shipping the materiel via scheduled truck from Virginia (Depot NV) to California. The result of these delays causes the total transportation costs to increase by $100 for each delay infraction. When the penalty is significantly increased to a higher number like one million, it becomes apparent that it is cheaper to switch shipping modes vice levying the penalty. For example, looking at the Delay Time column for *PEN*=1,000,000 dollars per day with the row labeled RDD there is a half day delay resulting in the $0.5M penalty being applied. When the RDD is reduced by one day (RDD-1) there is a one and a half day

delay resulting in a \$1.5M increase in transportation costs. However, when the RDD is decreased by two or more days the table shows it then becomes cheaper to switch to a faster, more expensive shipping mode in this case “Q” (Commercial Air Freight), rather than taking the penalty for delaying the materiel.

Similar what if analysis are shown in Table 4.17 for two depots.

			SIP using 2 Depots NV & DC							
			Pen = 100				*PEN* = 1,000,000			
	Depot	Customer	Mode	RDD	Delay Time	Cost	Mode	RDD	Delay Time	Cost
RDD	NV	VA 23511	9	9	0	\$201.06 K	9	9	0	\$201.06 K
	NV	FL 32508	S	4	0		S	4	0	
	DC	CA 92123	S	5.5	0		S	5.5	0	
RDD-1	NV	VA 23511	9	8	0	\$201.06 K	9	8	0	\$201.06 K
	NV	FL 32508	S	3	0		S	3	0	
	DC	CA 92123	S	4.5	0		S	4.5	0	
RDD-2	NV	VA 23511	9	7	0	\$201.16 K	9	7	0	\$881.29 K
	NV	FL 32508	S	2	1		Q	2	0	
	DC	CA 92123	S	3.5	0		S	3.5	0	
RDD-3	NV	VA 23511	9	6	0	\$201.26 K	9	6	0	\$881.29 K
	NV	FL 32508	Q	1	2		Q	1	0	
	DC	CA 92123	S	2.5	0		S	2.5	0	
RDD-4	NV	VA 23511	9	5	0	\$201.26 K	9	5	0	\$881.29 K
	NV	FL 32508	Q	1	2		Q	1	0	
	DC	CA 92123	S	1.5	0		S	1.5	0	

Table 4.17: Effects of Varying *PEN* Penalty for Two Depots

This table shows the effects of using 2 storage depots to store the same nozzle segment. SIP switches to a faster mode of shipment when the cost of the penalty out weighs the cost to use an alternative mode

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSION

To efficiently manage its stock of Depot Level Repairable (DLR) inventory, Navy Inventory Control Point (NAVICP) must be able to strategically determine where, and how much inventory to place in each distribution depot. NAVICP's current program, Uniform Inventory Control Processing system (UICP), identifies where to place its inventory based on historical percentages of regional demand. As discussed in Chapter 2, NAVICP has institutionalized specific policies to override UICP recommendations in order to reduce transportation costs. This policy follows closely with an inventory closest to vendor/ repair facility policy. The results of this study show that this policy is not cost effective and in most cases can increase overall transportations cost for each NIIN an average of 50 cents per pound-mile by requiring the use of more expensive modes of transportation.

A mixed integer program, Strategic Inventory Positioning (SIP), was developed to provide an alternative to NAVICP's current inventory positioning policy. SIP takes historical demand subject to the constraints identified in Chapter 3 and recommends new storage locations that would reduce transportation costs and customer wait time. SIP accomplishes this task by determining where and how much inventory to strategically located in each Defense Logistics Agency (DLA) distribution depot. By taking advantage of SIP's recommendations, NAVICP is able to capitalize upon DLA's new synchronized and scheduled trucking system by reducing transportation costs from dollars per pound to pennies per pound.

A cost comparative analysis was conducted using the storage locations recommended by UICP and comparing them to SIPs recommendations. This analysis shows that "inventory closest to customer" is the best storage policy. Since transportation costs are closely related to inventory placement, delivery of these items within the required delivery time standards established by the Uniform Materiel Movement and Issue Priority System can be achieved at a reduced transportation cost. This provides the Fleet a distribution system that is more responsive with improved

materiel availability. This in turn should prevent many high priority requisitions (i.e., CASREPS (casualty reports) and work stoppages) because materiel normally is in close proximity to the customer. This modification to the current stocking policy is made possible due to the Strategic Distribution Management Initiative as well as improvements in the trucking and small package carrier industries. Using SIP to identify the best location to stock inventory results in a reduction in the use of more expensive shipping modes such as FedEx and UPS.

This study primarily focuses on the cost of transporting DLRs from the distribution depot to the customer. The greatest cost savings is realized through the combined use of a new shipping mode and the storage recommendations from SIP. A preliminary analysis of the costs to ship from the repair facility to the distribution depot shows that this cost is negligible for high volume materiel and moderate for low volume materiel. Hence, the conclusion about reducing transportations costs from dollars per pound to pennies per pound appears to remain valid when using stock positioning recommendations from SIP and DLAs new synchronized and scheduled truck delivery system.

B. RECOMMENDATIONS

When computing the transportation costs associated with moving inventory, distance plays a major role in the cost equation. If materiel is strategically located such that the distance from the depot to the shipping region is minimized, a less expensive shipping mode can be utilized resulting in reduced transportation costs. Based on this ideology it is recommended that NAVICP adopt an inventory “closest to customer” positioning policy. Since new procurements are initially delivered to the designated depot under the terms of the current contract, this policy change mainly affects repaired items. When procurement contracts are renegotiated, the positioning recommendations from SIP can be useful in identifying optimal stocking locations. Current policy dictates that repaired DLRs be stored in the depot closest to the repair facility. This policy usually results in an increased shipping distance for new requisitions that also relates to a more expensive mode of transportation to ensure materiel reach the customer by the required delivery date.

SIP does not take into account all the costs associated with inventory positioning. Some of these are cost to store inventory that requires special handling equipment or special storage space such as hazardous material. Future research may involve extending SIP to develop a more comprehensive model that can take into account more of these costs. SIP also does not provide methods to determine the costs associated with relocating all NAVICP's DLR items from one depot to another. These costs involve additional issue, receipt, and transportation costs for both the issuing and receiving distribution depot. The model can be expanded further to encompass these costs and aid in determining the costs in inventory repositioning.

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APPENDIX

This appendix contains the results from SIP for the test set consisting of 178 National Item Identification Numbers (NIINs) as described in Chapter 4. The tables show the transportation costs associated with varying the number of distribution depots for each individual NIIN.

NIIN	UICP	1 Depot	2 Depots	3 Depots	4 Depots	5 Depots
000203211	$ 3,973.3 K	$ 303.7 K	$ 21.5 K	$ 8.2 K	$ 8.2 K	$ 3.2 K
000309552	$ 81,815.9 K	$ 7,036.9 K	$ 4,117.0 K	$ 2,409.3 K	$ 2,409.3 K	$ 1,326.2 K
000828666	$ 917.5 K	$ 55.4 K	$ 0.2 K	$ 0.2 K	$ 0.2 K	$ 0.2 K
001105521	$ 2,102.5 K	$ 107.1 K	$ 9.9 K	$ 6.8 K	$ 6.8 K	$ 5.6 K
001113645	$ 4,935.7 K	$ 168.5 K	$ 40.0 K	$ 17.8 K	$ 17.8 K	$ 14.4 K
001174118	$ 1,063.2 K	$ 174.3 K	$ 58.3 K	$ 54.4 K	$ 54.4 K	$ 54.4 K
001174629	$ 19,342.2 K	$ 745.1 K	$ 32.0 K	$ 12.9 K	$ 12.9 K	$ 12.2 K
001489231	$ 61,863.6 K	$ 7,818.8 K	$ 2,016.8 K	$ 1,944.4 K	$ 1,944.4 K	$ 1,879.1 K
001491319	$ 44,280.2 K	$ 4,135.0 K	$ 2,617.1 K	$ 1,511.5 K	$ 1,511.5 K	$ 1,214.0 K
001592298	$ 144,330.3 K	$ 3,247.2 K	$ 84.8 K	$ 72.6 K	$ 72.6 K	$ 70.9 K
001655838	$ 65,835.3 K	$ 1,294.3 K	$ 32.4 K	$ 23.9 K	$ 23.9 K	$ 22.4 K
001677675	$ 5,885.9 K	$ 689.8 K	$ 64.9 K	$ 32.1 K	$ 32.1 K	$ 14.7 K
001688769	$ 1,390.7 K	$ 138.7 K	$ 2.3 K	$ 1.5 K	$ 1.5 K	$ 1.4 K
001737439	$ 21,603.2 K	$ 4,431.9 K	$ 151.4 K	$ 79.6 K	$ 79.6 K	$ 78.5 K
001796510	$ 88,268.5 K	$ 6,406.8 K	$ 2,331.0 K	$ 1,873.5 K	$ 1,873.5 K	$ 1,641.5 K
002019809	$ 78,222.2 K	$ 10,366.6 K	$ 164.8 K	$ 108.4 K	$ 108.4 K	$ 103.7 K
002052253	$ 47,862.9 K	$ 4,232.1 K	$ 55.6 K	$ 37.8 K	$ 37.8 K	$ 37.0 K
002097984	$ 4,678.8 K	$ 392.8 K	$ 163.0 K	$ 92.0 K	$ 92.0 K	$ 55.0 K
004028651	$ 77,902.1 K	$ 4,673.0 K	$ 64.3 K	$ 51.2 K	$ 51.2 K	$ 50.1 K
004383487	$ 10,891.3 K	$ 4.0 K	$ 4.0 K	$ 4.0 K	$ 4.0 K	$ 4.0 K
008871944	$ 239,093.4 K	$ 16,362.6 K	$ 184.1 K	$ 173.1 K	$ 173.1 K	$ 163.2 K
008871969	$ 3,061.3 K	$ 251.1 K	$ 12.5 K	$ 5.4 K	$ 5.4 K	$ 2.9 K
009639444	$ 307.9 K	$ 166.6 K	$ 6.6 K	$ 5.9 K	$ 5.9 K	$ 5.7 K
009844752	$ 42,104.5 K	$ 5,496.1 K	$ 172.7 K	$ 74.8 K	$ 74.8 K	$ 74.8 K
010041804	$ 1,350,955.5 K	$ 54,859.7 K	$ 1,425.1 K	$ 796.5 K	$ 796.5 K	$ 796.5 K
010193892	$ 1,024.3 K	$ 122.3 K	$ 0.6 K	$ 0.6 K	$ 0.6 K	$ 0.6 K
010401531	$ 1,022.7 K	$ 76.2 K	$ 13.3 K	$ 8.7 K	$ 8.7 K	$ 5.5 K
010471348	$ 26,360.6 K	$ 2,651.6 K	$ 13.4 K	$ 11.8 K	$ 11.8 K	$ 11.8 K
010491153	$ 6,097.9 K	$ 461.3 K	$ 38.7 K	$ 17.1 K	$ 17.1 K	$ 13.7 K
010537272	$ 51,757.8 K	$ 3,197.9 K	$ 400.3 K	$ 271.3 K	$ 271.3 K	$ 118.8 K
010577834	$ 40,046.3 K	$ 2,424.9 K	$ 237.2 K	$ 126.2 K	$ 126.2 K	$ 91.0 K
010625846	$ 9,962.0 K	$ 736.5 K	$ 3.8 K	$ 3.8 K	$ 3.8 K	$ 3.8 K
010667325	$ 42,973.9 K	$ 3,829.8 K	$ 16.0 K	$ 16.0 K	$ 16.0 K	$ 16.0 K
010687755	$ 53,596.6 K	$ 4,912.4 K	$ 20.6 K	$ 20.6 K	$ 20.6 K	$ 20.6 K
010959170	$ 10,286.8 K	$ 1.4 K	$ 1.4 K	$ 1.4 K	$ 1.4 K	$ 1.4 K
011144422	$ 2,464.7 K	$ 422.8 K	$ 21.0 K	$ 13.4 K	$ 13.4 K	$ 6.2 K
011190647	$ 67,433.2 K	$ 3,353.7 K	$ 107.9 K	$ 79.0 K	$ 79.0 K	$ 71.7 K
011204885	$ 5,068.4 K	$ 404.5 K	$ 5.7 K	$ 3.2 K	$ 3.2 K	$ 3.1 K
011240903	$ 4,885.3 K	$ 335.7 K	$ 7.5 K	$ 3.8 K	$ 3.8 K	$ 3.7 K
011258013	$ 16,680.4 K	$ 2,423.6 K	$ 92.8 K	$ 44.6 K	$ 44.6 K	$ 37.4 K
011258904	$ 3,979.2 K	$ 291.7 K	$ 18.2 K	$ 8.2 K	$ 8.2 K	$ 7.0 K
011290138	$ 7,831.9 K	$ 796.5 K	$ 6.0 K	$ 4.9 K	$ 4.9 K	$ 4.9 K
011311435	$ 31,963.8 K	$ 3,181.0 K	$ 76.4 K	$ 47.4 K	$ 47.4 K	$ 35.1 K
011314730	$ 6,291.0 K	$ 386.0 K	$ 7.3 K	$ 4.0 K	$ 3.2 K	$ 3.2 K
011325908	$ 25,064.3 K	$ 1,325.5 K	$ 7.5 K	$ 7.2 K	$ 7.2 K	$ 7.2 K
011397177	$ 969.9 K	$ 96.2 K	$ 0.6 K	$ 0.4 K	$ 0.4 K	$ 0.4 K
011402298	$ 31,488.4 K	$ 3,022.6 K	$ 21.9 K	$ 20.6 K	$ 20.6 K	$ 20.6 K
011407620	$ 5,354.1 K	$ 1,835.8 K	$ 11.8 K	$ 9.6 K	$ 9.5 K	$ 9.5 K
011407627	$ 11,573.0 K	$ 895.4 K	$ 7.6 K	$ 6.4 K	$ 6.1 K	$ 5.9 K
011412735	$ 173,497.2 K	$ 13,391.6 K	$ 112.9 K	$ 83.8 K	$ 81.7 K	$ 81.7 K
011424304	$ 2,111.2 K	$ 234.4 K	$ 2.1 K	$ 1.4 K	$ 1.4 K	$ 1.3 K
011424347	$ 1,461.8 K	$ 127.7 K	$ 2.7 K	$ 2.7 K	$ 2.6 K	$ 2.6 K
011428815	$ 42,463.3 K	$ 3,687.5 K	$ 146.2 K	$ 63.7 K	$ 63.2 K	$ 63.2 K
011473037	$ 1,921.1 K	$ 3.9 K	$ 1.4 K	$ 1.4 K	$ 1.4 K	$ 1.4 K
011506731	$ 23,503.9 K	$ 4,234.8 K	$ 116.4 K	$ 74.4 K	$ 69.0 K	$ 64.5 K
011542869	$ 534.6 K	$ 48.6 K	$ 0.4 K	$ 0.3 K	$ 0.3 K	$ 0.3 K
011569309	$ 2,411.8 K	$ 248.3 K	$ 4.1 K	$ 2.6 K	$ 2.5 K	$ 2.5 K
011589679	$ 224,432.9 K	$ 7,871.2 K	$ 628.6 K	$ 606.2 K	$ 601.2 K	$ 601.2 K
011614443	$ 2,888.8 K	$ 378.4 K	$ 4.8 K	$ 3.3 K	$ 3.2 K	$ 3.2 K
011629391	$ 2,315.4 K	$ 114.6 K	$ 23.1 K	$ 6.9 K	$ 6.6 K	$ 6.6 K

NIIN	UICP	1 Depot	2 Depots	3 Depots	4 Depots	5 Depots
011629429	$ 2,826.7 K	$ 139.1 K	$ 12.0 K	$ 4.0 K	$ 3.7 K	$ 3.7 K
011629449	$ 2,436.4 K	$ 68.2 K	$ 22.4 K	$ 6.8 K	$ 6.6 K	$ 6.4 K
011635406	$ 2,819.5 K	$ 425.5 K	$ 6.1 K	$ 3.7 K	$ 3.7 K	$ 3.7 K
011664886	$ 1,594.6 K	$ 158.0 K	$ 0.7 K	$ 0.6 K	$ 0.6 K	$ 0.6 K
011758470	$ 25,533.1 K	$ 1,956.4 K	$ 23.5 K	$ 13.6 K	$ 13.4 K	$ 13.4 K
011771963	$ 17,274.7 K	$ 1,563.7 K	$ 13.8 K	$ 12.9 K	$ 12.9 K	$ 12.9 K
011790560	$ 1,650.8 K	$ 104.6 K	$ 6.1 K	$ 2.1 K	$ 2.1 K	$ 2.1 K
011861672	$ 37,100.1 K	$ 3,558.6 K	$ 79.4 K	$ 43.5 K	$ 37.6 K	$ 36.7 K
011911817	$ 1,471.1 K	$ 45.4 K	$ 0.3 K	$ 0.3 K	$ 0.3 K	$ 0.3 K
011917057	$ 163,306.0 K	$ 16,433.4 K	$ 449.7 K	$ 214.1 K	$ 209.0 K	$ 209.0 K
011932157	$ 14,996.5 K	$ 790.5 K	$ 48.0 K	$ 34.0 K	$ 22.4 K	$ 21.6 K
011987705	$ 597.7 K	$ 43.8 K	$ 0.3 K	$ 0.2 K	$ 0.2 K	$ 0.2 K
012016313	$ 41,256.2 K	$ 3,125.7 K	$ 13.0 K	$ 13.0 K	$ 13.0 K	$ 13.0 K
012019481	$ 867.9 K	$ 50.6 K	$ 0.3 K	$ 0.3 K	$ 0.3 K	$ 0.3 K
012027264	$ 146,384.1 K	$ 13,096.9 K	$ 881.1 K	$ 385.0 K	$ 336.5 K	$ 336.5 K
012029228	$ 4,251.4 K	$ 137.3 K	$ 4.6 K	$ 1.9 K	$ 1.8 K	$ 1.7 K
012138145	$ 373.9 K	$ 292.3 K	$ 13.6 K	$ 9.7 K	$ 6.2 K	$ 5.8 K
012185553	$ 31,845.4 K	$ 2,596.5 K	$ 52.6 K	$ 24.9 K	$ 24.4 K	$ 24.4 K
012204747	$ 85,627.5 K	$ 11,372.8 K	$ 984.2 K	$ 644.6 K	$ 347.0 K	$ 344.9 K
012225163	$ 4,121.0 K	$ 574.8 K	$ 11.0 K	$ 4.4 K	$ 4.4 K	$ 4.4 K
012238403	$ 8,063.5 K	$ 1,421.7 K	$ 201.8 K	$ 85.6 K	$ 85.6 K	$ 85.6 K
012240484	$ 61,395.2 K	$ 3,433.3 K	$ 621.6 K	$ 257.8 K	$ 222.7 K	$ 222.7 K
012265321	$ 19,138.1 K	$ 2,474.8 K	$ 18.0 K	$ 14.0 K	$ 14.0 K	$ 14.0 K
012274925	$ 74,500.5 K	$ 2,847.7 K	$ 1,778.3 K	$ 1,389.7 K	$ 1,389.7 K	$ 1,389.7 K
012364761	$ 125,102.2 K	$ 8,042.6 K	$ 195.2 K	$ 110.4 K	$ 110.4 K	$ 110.4 K
012374089	$ 55,738.2 K	$ 4,254.4 K	$ 73.6 K	$ 41.7 K	$ 40.3 K	$ 39.2 K
012423695	$ 5,305.4 K	$ 363.8 K	$ 5.6 K	$ 3.5 K	$ 3.2 K	$ 3.1 K
012423760	$ 5,634.2 K	$ 489.0 K	$ 3.5 K	$ 3.4 K	$ 3.3 K	$ 3.3 K
012429714	$ 48,955.9 K	$ 3,676.3 K	$ 147.6 K	$ 87.4 K	$ 65.2 K	$ 62.1 K
012567691	$ 35,778.1 K	$ 1,772.4 K	$ 220.9 K	$ 129.7 K	$ 115.6 K	$ 111.1 K
012643928	$ 352,328.5 K	$ 40,521.6 K	$ 13,469.5 K	$ 10,618.0 K	$ 9,378.5 K	$ 9,378.5 K
012653659	$ 42,255.6 K	$ 3,206.0 K	$ 32.2 K	$ 24.7 K	$ 24.4 K	$ 24.4 K
012711063	$ 3,644.8 K	$ 327.4 K	$ 5.6 K	$ 3.2 K	$ 3.0 K	$ 3.0 K
012743433	$ 10,769.3 K	$ 921.2 K	$ 16.3 K	$ 9.4 K	$ 9.4 K	$ 9.4 K
012743443	$ 42,434.3 K	$ 4,586.8 K	$ 62.6 K	$ 35.5 K	$ 34.6 K	$ 34.6 K
012743482	$ 23,575.8 K	$ 1,928.9 K	$ 216.3 K	$ 80.9 K	$ 80.9 K	$ 80.9 K
012866684	$ 17,015.7 K	$ 1,738.3 K	$ 253.1 K	$ 75.6 K	$ 75.0 K	$ 75.0 K
012866685	$ 10,563.9 K	$ 1,790.7 K	$ 94.3 K	$ 43.6 K	$ 37.1 K	$ 36.0 K
012965754	$ 55,242.1 K	$ 5,348.3 K	$ 401.7 K	$ 399.5 K	$ 399.5 K	$ 399.5 K
013000940	$ 97,250.7 K	$ 8,495.1 K	$ 83.4 K	$ 56.5 K	$ 54.6 K	$ 54.4 K
013010814	$ 9,871.7 K	$ 856.0 K	$ 29.5 K	$ 12.2 K	$ 11.9 K	$ 11.9 K
013151717	$ 7,842.1 K	$ 566.6 K	$ 3.0 K	$ 2.7 K	$ 2.7 K	$ 2.7 K
013163474	$ 665,610.2 K	$ 60,387.6 K	$ 2,016.1 K	$ 937.2 K	$ 900.5 K	$ 898.4 K
013164973	$ 573.3 K	$ 3,484.9 K	$ 3,299.5 K	$ 3,380.8 K	$ 51.5 K	$ 32.7 K
013174521	$ 111,411.5 K	$ 7,935.7 K	$ 91.1 K	$ 55.3 K	$ 55.3 K	$ 55.3 K
013189077	$ 4,268.3 K	$ 382.7 K	$ 3.2 K	$ 3.0 K	$ 3.0 K	$ 3.0 K
013205055	$ 80,994.8 K	$ 3,128.9 K	$ 39.8 K	$ 39.8 K	$ 39.8 K	$ 39.8 K
013205057	$ 181,750.7 K	$ 14,905.9 K	$ 74.2 K	$ 74.2 K	$ 74.2 K	$ 74.2 K
013206854	$ 7,470.0 K	$ 727.7 K	$ 12.1 K	$ 6.1 K	$ 6.0 K	$ 6.0 K
013416041	$ 39,906.0 K	$ 2,746.3 K	$ 79.1 K	$ 47.5 K	$ 39.5 K	$ 37.8 K
013432609	$ 65,809.3 K	$ 6,444.5 K	$ 63.6 K	$ 43.7 K	$ 43.2 K	$ 43.2 K
013437026	$ 158,963.0 K	$ 15,133.3 K	$ 345.5 K	$ 212.3 K	$ 195.3 K	$ 188.8 K
013453117	$ 40,598.2 K	$ 1,149.9 K	$ 67.7 K	$ 59.6 K	$ 54.1 K	$ 52.2 K
013506640	$ 70,239.9 K	$ 5,311.6 K	$ 737.6 K	$ 737.6 K	$ 737.6 K	$ 737.6 K
013513373	$ 35,461.1 K	$ 3,064.5 K	$ 60.5 K	$ 35.8 K	$ 31.1 K	$ 30.6 K
013538344	$ 17,816.3 K	$ 788.3 K	$ 15.9 K	$ 9.5 K	$ 9.5 K	$ 9.5 K
013571941	$ 294,904.3 K	$ 21.5 K	$ 21.5 K	$ 21.5 K	$ 21.5 K	$ 21.5 K
013584354	$ 62,102.0 K	$ 4,883.8 K	$ 23.3 K	$ 22.9 K	$ 22.9 K	$ 22.9 K
013664970	$ 144,047.6 K	$ 15,314.3 K	$ 305.2 K	$ 174.3 K	$ 168.8 K	$ 168.8 K

NIIN	UICP	1 Depot	2 Depots	3 Depots	4 Depots	5 Depots
013693370	$ 24,540.1 K	$ 1,573.3 K	$ 26.9 K	$ 21.6 K	$ 20.0 K	$ 20.0 K
013841454	$ 59,870.3 K	$ 5,815.1 K	$ 38.4 K	$ 29.3 K	$ 29.3 K	$ 29.3 K
013887479	$ 27,578.6 K	$ 2,281.4 K	$ 304.9 K	$ 244.8 K	$ 191.2 K	$ 157.8 K
013896529	$ 28,173.4 K	$ 3,139.4 K	$ 13.4 K	$ 13.4 K	$ 13.4 K	$ 13.4 K
013910502	$ 12,222.9 K	$ 1,111.9 K	$ 11.9 K	$ 11.4 K	$ 11.2 K	$ 11.2 K
013931180	$ 19,083.8 K	$ 1,198.5 K	$ 23.0 K	$ 13.6 K	$ 12.4 K	$ 12.3 K
013947572	$ 38,166.8 K	$ 3,014.3 K	$ 48.1 K	$ 44.4 K	$ 40.9 K	$ 40.9 K
013949231	$ 17,367.1 K	$ 1,968.2 K	$ 8.3 K	$ 8.3 K	$ 8.3 K	$ 8.3 K
013960647	$ 83,547.0 K	$ 7,201.9 K	$ 427.7 K	$ 196.1 K	$ 190.9 K	$ 190.9 K
013986528	$ 9,122.2 K	$ 496.5 K	$ 22.2 K	$ 7.5 K	$ 5.3 K	$ 5.0 K
013987155	$ 43,706.1 K	$ 2,379.8 K	$ 33.0 K	$ 24.0 K	$ 21.8 K	$ 21.0 K
013988561	$ 58,472.7 K	$ 5,388.8 K	$ 247.7 K	$ 163.1 K	$ 109.1 K	$ 105.5 K
014002184	$ 2,841.5 K	$ 164.5 K	$ 12.8 K	$ 5.3 K	$ 5.2 K	$ 5.2 K
014077972	$ 25,042.6 K	$ 1,659.6 K	$ 12.9 K	$ 11.3 K	$ 10.9 K	$ 10.9 K
014080379	$ 11,524.3 K	$ 2,409.7 K	$ 19.8 K	$ 18.5 K	$ 18.5 K	$ 18.5 K
014082090	$ 3,712.4 K	$ 336.5 K	$ 2.2 K	$ 2.0 K	$ 1.9 K	$ 1.9 K
014086574	$ 42,956.1 K	$ 6,981.2 K	$ 170.9 K	$ 117.1 K	$ 89.6 K	$ 86.2 K
014091097	$ 1,985.0 K	$ 824.0 K	$ 49.3 K	$ 30.6 K	$ 30.6 K	$ 30.6 K
014106751	$ 2,009.6 K	$ 851.5 K	$ 82.9 K	$ 32.2 K	$ 27.5 K	$ 26.6 K
014115215	$ 77,320.3 K	$ 10,566.6 K	$ 1,014.7 K	$ 407.7 K	$ 314.6 K	$ 314.6 K
014131049	$ 64,061.3 K	$ 5,584.2 K	$ 66.6 K	$ 43.6 K	$ 41.1 K	$ 40.1 K
014140187	$ 576.3 K	$ 77.6 K	$ 8.8 K	$ 5.3 K	$ 5.3 K	$ 5.3 K
014144946	$ 875.2 K	$ 28.4 K	$ 0.4 K	$ 0.4 K	$ 0.4 K	$ 0.4 K
014145895	$ 4,966.0 K	$ 2,342.2 K	$ 2,412.5 K	$ 2,150.2 K	$ 128.3 K	$ 110.9 K
014148410	$ 1,078,989.5 K	$ 1,694.2 K	$ 646.6 K	$ 646.6 K	$ 646.6 K	$ 646.6 K
014245924	$ 69,104.2 K	$ 7,339.0 K	$ 74.4 K	$ 62.0 K	$ 59.0 K	$ 55.9 K
014252532	$ 42,089.7 K	$ 63.6 K	$ 24.3 K	$ 24.3 K	$ 24.3 K	$ 24.3 K
014254919	$ 332,076.2 K	$ 15,725.5 K	$ 274.2 K	$ 177.3 K	$ 177.3 K	$ 177.3 K
014254920	$ 197,023.3 K	$ 8,769.1 K	$ 75.0 K	$ 71.7 K	$ 71.7 K	$ 71.7 K
014256322	$ 288,399.6 K	$ 10,524.8 K	$ 119.2 K	$ 119.2 K	$ 119.2 K	$ 119.2 K
014353715	$ 71,837.5 K	$ 7,952.5 K	$ 146.3 K	$ 78.9 K	$ 78.9 K	$ 78.9 K
014353720	$ 274,869.9 K	$ 15,430.1 K	$ 115.8 K	$ 115.8 K	$ 115.8 K	$ 115.8 K
014367087	$ 21,752.3 K	$ 1,065.1 K	$ 13.8 K	$ 11.5 K	$ 11.5 K	$ 11.5 K
014382596	$ 10,090.3 K	$ 938.8 K	$ 45.9 K	$ 26.4 K	$ 18.2 K	$ 18.2 K
014388413	$ 19,584.0 K	$ 2,148.0 K	$ 9.1 K	$ 9.1 K	$ 9.1 K	$ 9.1 K
014421596	$ 37,378.0 K	$ 2,874.1 K	$ 89.7 K	$ 46.6 K	$ 39.3 K	$ 38.2 K
014437394	$ 652.3 K	$ 149.6 K	$ 6.4 K	$ 2.4 K	$ 2.4 K	$ 2.4 K
014456362	$ 2,131.8 K	$ 133.2 K	$ 1.0 K	$ 0.8 K	$ 0.8 K	$ 0.8 K
014494496	$ 12,139.1 K	$ 5.9 K	$ 0.9 K	$ 0.9 K	$ 0.9 K	$ 0.9 K
014555217	$ 177,348.3 K	$ 13,578.9 K	$ 161.9 K	$ 113.5 K	$ 103.6 K	$ 103.6 K
014556975	$ 3,922.9 K	$ 306.6 K	$ 3.5 K	$ 2.5 K	$ 2.3 K	$ 2.3 K
014585910	$ 381.8 K	$ 85.5 K	$ 2.4 K	$ 1.4 K	$ 1.3 K	$ 1.2 K
014638057	$ 28,361.3 K	$ 4,560.0 K	$ 903.3 K	$ 792.4 K	$ 726.2 K	$ 666.6 K
014650843	$ 7,653.4 K	$ 1,431.9 K	$ 14.8 K	$ 13.7 K	$ 13.7 K	$ 13.7 K
014650844	$ 15,071.3 K	$ 2,866.6 K	$ 56.5 K	$ 32.2 K	$ 30.6 K	$ 30.6 K
014651509	$ 525.7 K	$ 109.9 K	$ 65.7 K	$ 65.7 K	$ 65.7 K	$ 65.7 K
014653534	$ 384,004.0 K	$ 18,256.9 K	$ 1,057.2 K	$ 487.6 K	$ 474.4 K	$ 474.4 K
014660084	$ 164,017.1 K	$ 15,018.9 K	$ 64.0 K	$ 64.0 K	$ 64.0 K	$ 64.0 K
014673556	$ 3,822.2 K	$ 374.2 K	$ 5.0 K	$ 3.5 K	$ 3.3 K	$ 3.2 K
014673559	$ 43,368.4 K	$ 2,491.2 K	$ 787.5 K	$ 470.3 K	$ 269.5 K	$ 269.3 K
014743711	$ 8,376.7 K	$ 544.6 K	$ 13.1 K	$ 9.6 K	$ 8.0 K	$ 8.0 K
014763224	$ 37,919.1 K	$ 3,061.0 K	$ 113.6 K	$ 48.3 K	$ 45.3 K	$ 44.6 K
014871910	$ 150,316.6 K	$ 11,436.0 K	$ 337.3 K	$ 159.8 K	$ 153.4 K	$ 153.4 K
014948719	$ 673,895.2 K	$ 31,409.4 K	$ 202.9 K	$ 141.9 K	$ 141.9 K	$ 141.9 K
014960533	$ 1,243.2 K	$ 141.8 K	$ 169.1 K	$ 168.6 K	$ 156.1 K	$ 17.6 K
014980241	$ 111,169.2 K	$ 12,260.9 K	$ 236.4 K	$ 172.4 K	$ 110.2 K	$ 110.2 K
998919977	$ 576.0 K	$ 86.6 K	$ 18.6 K	$ 13.7 K	$ 10.1 K	$ 10.1 K
Total	$ 11,954,885.1 K	$ 762,721.9 K	$ 54,739.0 K	$ 39,496.8 K	$ 31,703.3 K	$ 29,392.8 K
Reduction		$ 11,192,163.2 K	$ 11,900,146.1 K	$ 11,915,388.3 K	$ 11,923,181.8 K	$ 11,925,492.3 K

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